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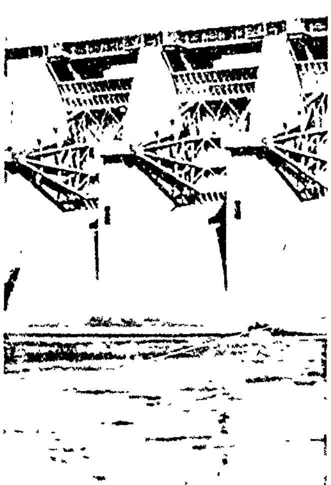

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MANAGEMENT APPROACHES FOR WATER QUALITY ENHANCEMENT AT WHITNEY POINT AND EAST SIDNEY LAKES NEW YORK

by

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Increased demands on the multi-use resource provided by reservoirs require development of comprehensive management plans for maintenance of acceptable water quality. Identification of potential for adverse quality, which may impair usage, is followed by assessments of enhancement techniques and application, if feasible.

These principles were applied at two Corps of Engineers reservoirs for assessment of water quality conditions and delineation of management opportunities for water quality enhancement. Water quality is described from detailed studies conducted during the summer growing season. Interactions with other agencies with primary responsibilities in the watershed are detailed. Perceptions of water quality from user viewpoints, regional comparisons, and textbook values are presented. Management opportunities are identified, and a management plan is recommended for one of the reservoirs, East Sidney Lake, New York.

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PREFACE

The study described in this report was sponsored by the US Army Engineer District, Baltimore (NAB), and was conducted by the US Army Engineer Waterways Experiment Station (WES) under Intra-Army Order No. E86888033, dated 4 April 1988. Mr. Pete Juhle, Chief of the Water Control Management Section, NAB, served as point of contact. Additional support was provided as part of the Water Quality Management for Reservoirs and Tailwaters Demonstration of the Water Operations Technical Support (WOTS) Program. The WOTS Program was sponsored by the Headquarters, US Army Corps of Engineers (HQUSACE). Technical Monitors for WOTS were Mr. David Buelow, Dr. John Bushman, and Mr. James L. Gottesman, HQUSACE. Program Manager of WOTS was Mr. J. L. Decell of the Environmental Laboratory (EL), WES.

This report was prepared by Mr. Steven L. Ashby and Dr. Robert H. Kennedy of the EL. Part VI and Appendix D were prepared by Mr. Jim E. Henderson of the EL. Participating in the conduct of the study were Messrs. Joe Carroll and William Jabour of the EL and Messrs. Tom Hurlburt, Bob Edwards, John McKown, and Henry Brunelle (NAB). Phytoplankton identification was conducted by Dr. William Taylor of the EL. Field sampling was conducted by Mr. Jim Mitchell under the supervision of Dr. John Titus, State University of New York, Binghamton, NY. Field assistance at Whitney Point Lake was provided by personnel at Dorchester Park, Broome County Parks and Recreation Department, Binghamton, NY.

The study was conducted under the direct supervision of Dr. Thomas L. Hart, Chief, Aquatic Processes and Effects Group, and under the general supervision of Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division, and Dr. John Harrison, Chief, EL. Technical reviews of this report, provided by Dr. Robert F. Gaugush and Dr. William Taylor, are gratefully acknowledged.

COL Larry B. Fulton, EN, was Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

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CONTENTS

MANAGEMENT APPROACHES FOR WATER QUALITY ENHANCEMENT AT WHITNEY POINT AND EAST SIDNEY LAKES, NEW YORK

PART I: INTRODUCTION

Excessive addition of nutrients to lakes and reservoirs, either from natural or anthropogenic sources, may promote adverse water quality conditions. These include low dissolved oxygen levels in bottom waters, increased concentrations of dissolved nutrients and metals, decreased water storage due to increased siltation, and nuisance phytoplankton "blooms." Since phytoplankton blooms often impair water supply, and reduce recreation and aesthetic value, water quality enhancement efforts logically focus on control of phytoplankton production.

Control of phytoplankton production, or algal biomass, is often pursued as a function of nutrient availability. It is generally accepted that phosphorus is the element which most frequently limits production when nutrient resources are depleted. The well-established relationship between phosphorus and algal chlorophyll (Sakamoto 1966) suggests that control of algal biomass may be achieved through control of phosphorus availability.

Maintenance of good water quality is desirable since water quality impacts the use of a water resource. Reservoirs are multi-use resources providing flood control, hydroelectric power, water supply, recreation, and fish and wildlife habitat. Increased demands on these multi-use resources require development of comprehensive management plans, specifically for the enhancement of water quality.

Development of a water quality management plan requires a logical and orderly approach that can be easily modified for specific applications. A water quality management plan would include elements such as problem identification, delineation of management objectives, identification of feasible approaches, implementation of enhancement techniques, and evaluation of the effects on water quality.

Identification of adverse water quality is often based on analysis of existing data. Assessment of existing data is usually more cost-effective than collection of field data, however, historical records may be incomplete, lacking in pertinent data, or based on unacceptable methodology. Initial evaluation of existing data identifies deficiencies in the data set and

provides a basis for efficient planning of supplementary field investigations to obtain additional data.

Once water quality problems and their sources have been identified, management objectives can be clearly defined. Approaches for meeting management objectives may be identified and, if sufficient data exists, detailed analyses of feasible management techniques can be conducted. Limitations due to operational requirements, watershed characteristics and land uses, external loadings, and user perceptions must be considered in evaluations of potential management techniques.

Implementation of management techniques, where required, and evaluation of the effectiveness on water quality enhancement are the final steps in the water quality management plan.

These principles are being implemented by the US Army Engineer, Baltimore District (NAB), in addition to routine water quality monitoring at its water projects. In an effort to evaluate management potential, the Environmental Laboratory (EL) of the Waterways Experiment Station (WES) conducted water quality assessments at five NAB projects (Kennedy et al. 1988). Study efforts focused on assessment of nutrient loading and related eutrophication processes. Evaluation of existing NAB data was supplemented with intensive data collection conducted during the summer growing season.

The major conclusions of the Kennedy et al. (1988) study are given below and were used to develop the comprehensive study presented here:

1. Four of the five projects exhibited water quality conditions characteristic of eutrophic systems including high algal biomass, frequent nuisance algal blooms, reduced water clarity, excessive nutrient concentrations, hypolimnetic anoxia, and hypolimnetic sulfide production. Tioga Lake is an exception due to the dominating influence of acid mine drainage on inflow water quality.

2. Management opportunities currently exist only at Whitney Point and East Sidney Lakes. Tioga and Hammond Lakes are currently being successfully operated to maintain acceptable pH levels in the discharge. The normal pool elevation in Cowanesque Lake will be raised bringing about unstable water quality conditions for an interim period.

3. Significant enhancement of water quality due to increased thermal stability via operational changes at Whitney Point and East Sidney Lakes is limited due to low thermal stability of the summer pools. Both lakes are subject to intermittent mixing throughout the summer growing season which further exacerbates eutrophic processes. Changes in withdrawal patterns would have a more pronounced effect

on thermal stability at East Sidney Lake, but thermal stability would not be increased enough to eliminate intermittent mixing.

4. Land use patterns in the watershed markedly impact water quality at each lake.

As recommended in the previous study (Kennedy et al. 1988), the Baltimore District and the WES Environmental Laboratory initiated a comprehensive study at Whitney Point and East Sidney Lakes including the following study elements:

1. Additional data were collected at Whitney Point and East Sidney Lakes to provide a more complete understanding of water quality conditions and the relationship between the watersheds to water quality of the lakes.

2. A comprehensive inventory of land use patterns in the watershed of East Sidney Lake was conducted.

3. User perceptions of water quality conditions were determined at the projects.

4. Computer modeling techniques were utilized to evaluate management approaches.

The objective of this study was to identify management approaches for water quality enhancement at Whitney Point and East Sidney Lakes in the Baltimore District. Detailed sampling and analytical methods, water quality data, a complete listing of phytoplankton species, detailed evaluation of the user survey, and assessment of computer simulation are included as Appendixes A-E, respectively. An evaluation of an enhancement technique recommended for East Sidney Lake is presented in Appendix F.

PART II: PROJECT LOCATION AND DESCRIPTION

Whitney Point and East Sidney Lakes are located in the watershed of the North Branch of the Susquehanna River in south central New York (Figure 1). Authorized by the Flood Control Act of 22 June 1936, the projects provide flood control protection for towns in southern New York and eastern Pennsylvania. Whitney Point and East Sidney Lakes were filled in 1942 and 1950, respectively.

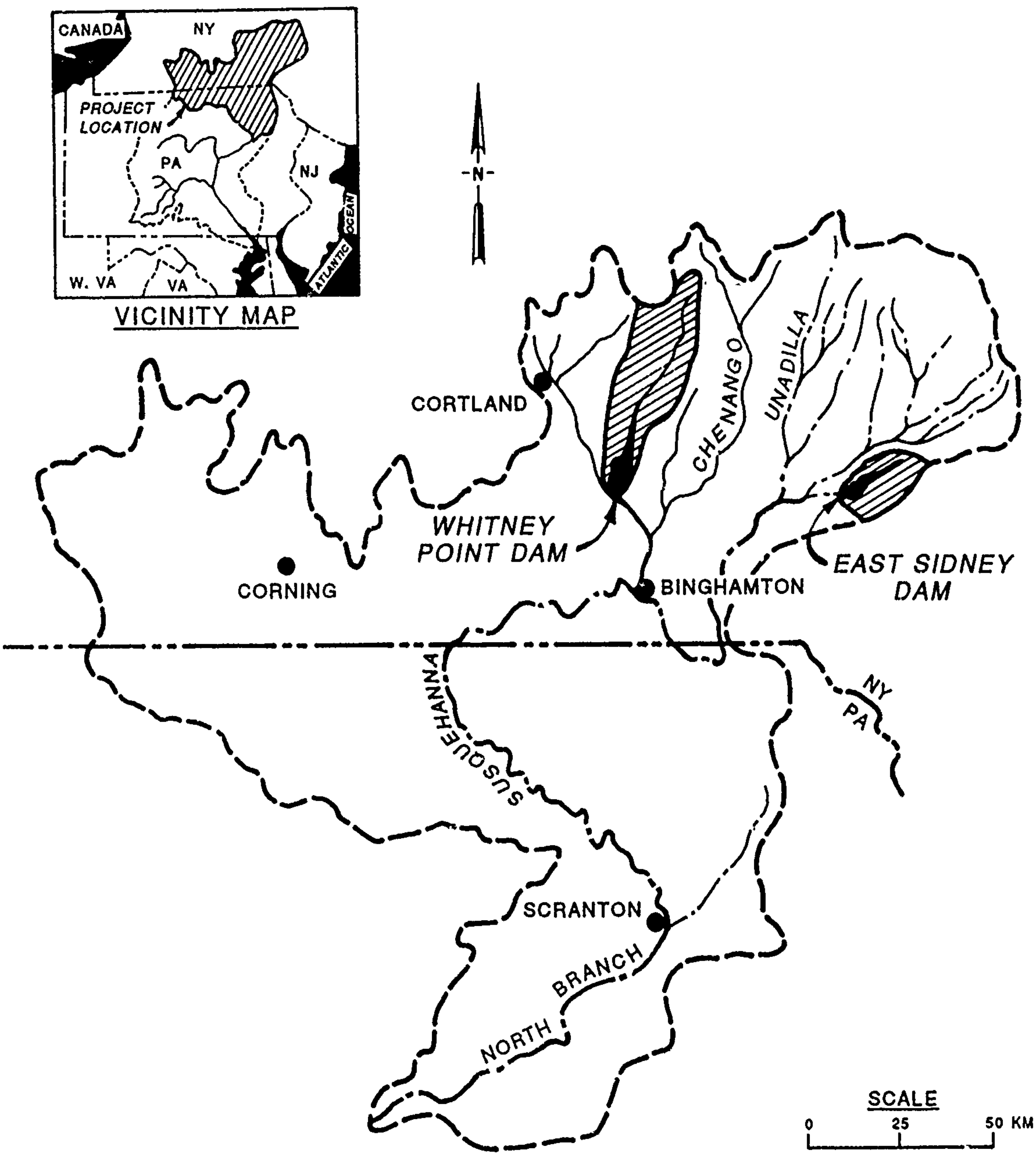


Figure 1. Locations of Whitney Point and East Sidney Lakes

Whitney Point Dam is a rolled earth filled embankment structure with an outlet tower and operating house located near the left abutment. A saddle-type spillway with an Ogee weir is located in the center section. The main feature of East Sidney Dam is a concrete gravity section with controlled outlet conduits. The spillway is an uncontrolled Ogee weir. Detailed structural features of Whitney Point and East Sidney Dams are presented in US Army Corps of Engineers (1984 and 1983a, respectively). Physical characteristics of each project are presented in Table 1.

Releases from Whitney Point and East Sidney Dams are via bottom gates and opportunity for release at other depths does not exist at this time. Outlet works at Whitney Point Dam consist of an outlet tunnel controlled by three 1.5- by 3.0-m service gates with inverts at 289.56 m National Geodetic Vertical Datum (NGVD). At East Sidney Dam, the outlet works consist of five 1.1- by 1.8-m gate-controlled conduits with inverts at 339.85 m NGVD. Consequently, at summer pool elevations, discharge waters originate from near 7 and 11 m of depth, respectively, from each lake. These depths are well below the mean depths for summer pool elevations and summer releases result in the removal of cooler, bottom water.

Both projects were originally designed and operated for flood control. However, seasonal recreation pool elevations were established in 1963 at Whitney Point Lake and in 1965 at East Sidney Lake. Currently, both projects are operated for flood control, as well as for such recreational uses as, swimming, picnicking, boating, fishing, and camping.

Current water control plans require the establishment of recreational pools from 15 May through 30 November and conservation pools from 1 December to 14 May to provide for flood control. A minimum pool elevation (294.4 m NGVD) is maintained at Whitney Point Lake for fish habitat at the request of the Conservation Department, State of New York. The greatest storage requirements occur in association with snowmelt and increased runoff during January through April. Retention of spring high flow allows for increased pool elevations required for summer recreation. Detailed operational characteristics and rule curves for Whitney Point and East Sidney Lakes are presented in US Army Corps of Engineers (1984 and 1983a, respectively).

Three public use areas exist at Whitney Point Lake. The most frequently used area is Dorchester Park, which is located near the dam and operated by Broome County, New York. This area serves as a day-use area and has no provisions for overnight camping. Lisle Recreation Area, located near mid-lake,

and Upper Lisle Recreation Area, located at the inflow, provide swimming, picnicking, and overnight camping. An overlook area provides a vista of the dam and spillway, and fishing and canoeing are available in the tailwater area.

East Sidney Lake has one public use area, located near the dam, which includes a beach and dressing area, sanitary facilities, and areas for picnicking, camping, and boat launching and docking. These facilities are maintained by the town of Sidney, New York.

PART III: WATERSHED DESCRIPTIONS

Project watersheds, both of which are located in the Glaciated Appalachian Plateau (US Army Corps of Engineers, 1983a and 1984), exhibit similarities in topography and soils. Gently rolling hills and deep valleys with moderately steep side slopes are primary watershed features. Glacial action deepened most of the valleys and refilled them with overburden, chiefly till consisting of gravel, sands, silts, and clays. Consequently, soils are well-drained and numerous springs are present in the watersheds.

Mean annual precipitation for this region (as recorded at Whitney Point Lake) is 91 cm, including a mean annual snowfall of 224 cm. Mean monthly precipitation data are unimodally distributed with peak levels occurring as summer and fall thunderstorms (Figure 2). These storms are characterized as having high intensity yet moderate in duration, and are accompanied by relatively high surface runoff. Highest runoff volumes, however, occur in late winter and early spring in association with snowmelt. Runoff during this period is characterized by lower precipitation intensities, but longer duration than summer and fall floods.

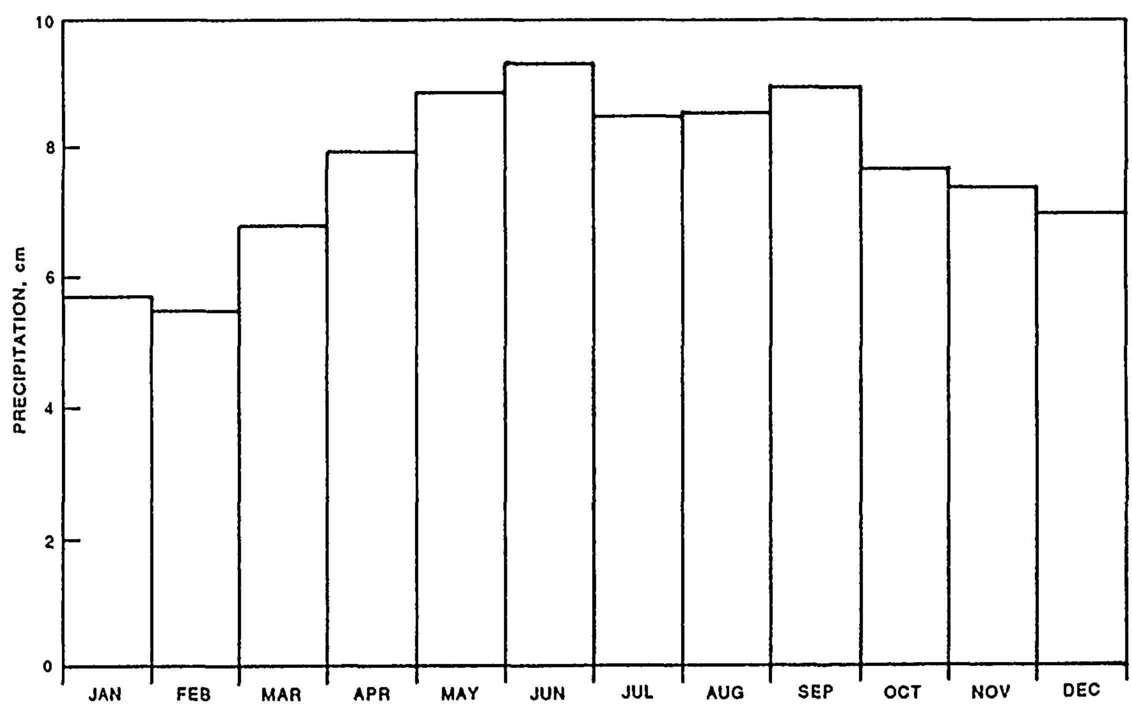


Figure 2. Mean monthly precipitation data for the project watersheds

The Otselic River is the primary inflow to Whitney Point Lake with a mean annual flow near 12 cu m/sec (Figure 3). The average runoff is

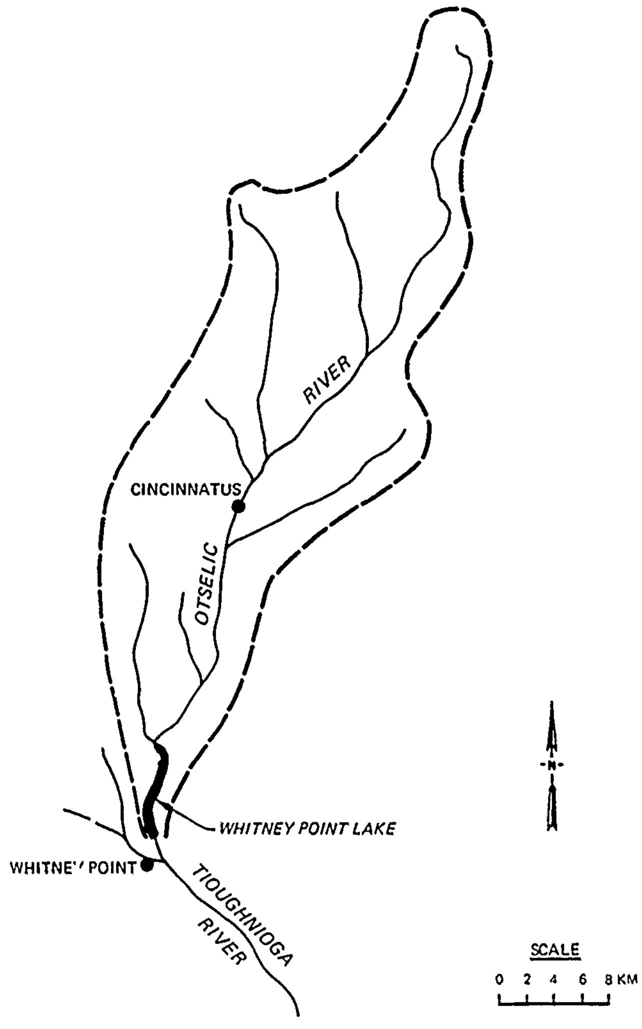


Figure 3. Whitney Point Lake watershed

approximately 56 cm per year. Ouleout Creek is the major inflow to East Sidney Lake with a mean annual flow near 4.6 cu m/sec (Figure 4). A secondary stream, Handsome Creek, drains approximately 25 per cent of the watershed and enters East Sidney Lake in the headwater region. The average runoff at East Sidney Lake is approximately 48 cm per year.

Demographic characteristics and land use patterns in the watersheds reflect the rural economy of the region. Although many small towns are located in the area, major urban areas are not present in the watersheds. Dairy and nondairy cattle operations and associated agriculture are the predominant land uses with woodlots occupying areas unsuitable for row crop cultivation or pasture.

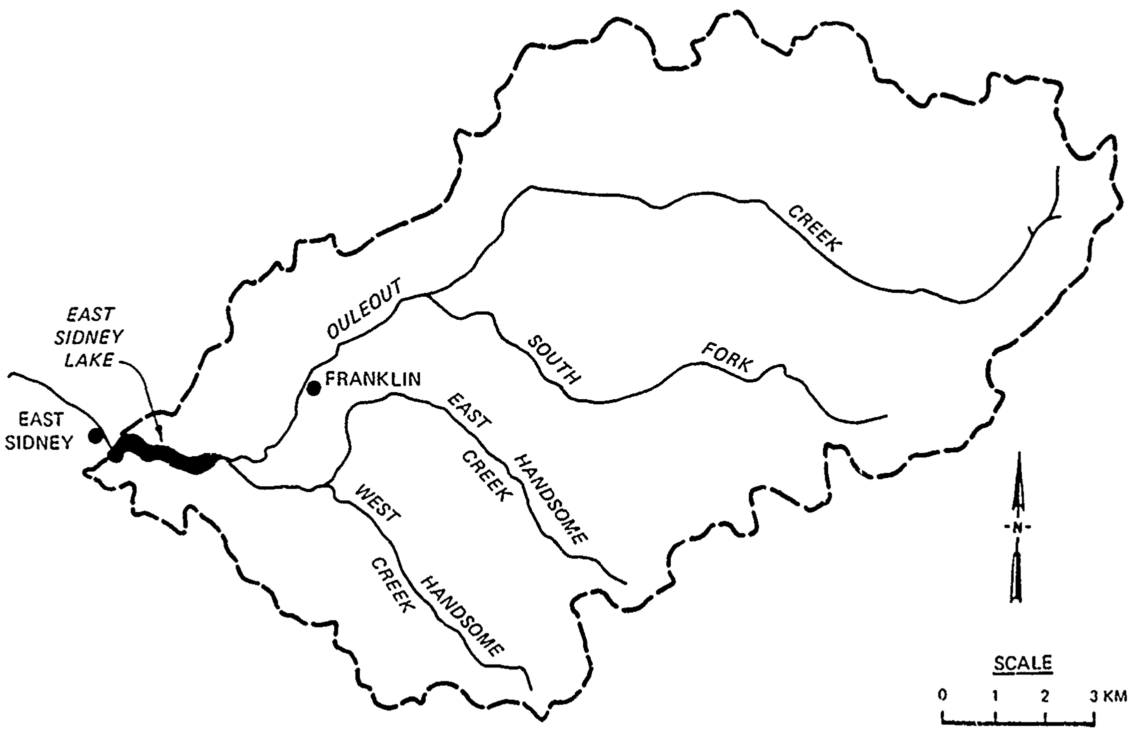


Figure 4. East Sidney Lake watershed

Analysis of infrared, color stereoscopic photographs can provide detailed information of watershed characteristics and land use patterns which may impact water quality. Aerial photographs of project watersheds were taken in April 1988, prior to pronounced spring foliage development, for detailed inventory of land use characteristics. Identification and enumeration of surface drainage connections, animal activity sites, access points to streams, and other land uses were conducted for the East Sidney Lake watershed. A detailed atlas depicting land uses, animal activities, and hydrologic pathways was prepared and a complete numerical tabulation of data for the East Sidney Lake watershed is available on computer disk. Detailed methods are presented in Appendix A.

In general, land cover in the watershed is comprised of pastures, row crop fields, forested areas, and old fields with volunteer woody growth. Agricultural land uses principally support cattle operations which account for 97% of the animal activity in the watershed (Table 2). These sites are primarily unconfined, i.e. animals not confined to a small area but identifiable at a point of concentration such as a barn. The remaining 3% of the sites were unconfined horse activity and confined poultry and swine operations.

Sites of animal activity were relatively uniform in distribution within the watershed (Figure 5). The majority of sites were in close proximity to streams and numerous areas of direct animal access to streams were identified. Potential problem areas such as erodible stream or road banks, clear-cut forested areas, nonagricultural disturbed areas, or overly grazed pastures were minimal.

Numerous springs were identified and perennial drains (streams with well-defined channels and continuous flow) dominated the hydrologic features of the watershed. Some seeps and other wet areas were observed, but intermittent and ephemeral drains were not readily apparent.

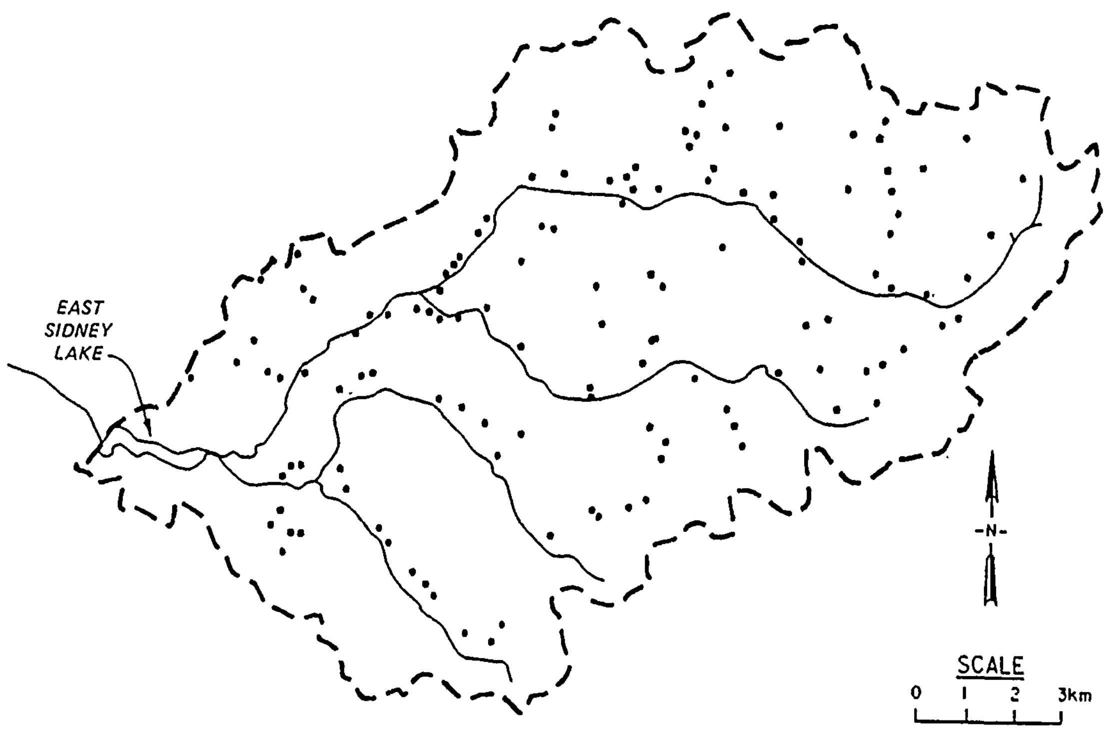


Figure 5. Drainage basins and sites of animal activities, East Sidney Lake watershed

PART IV: EXTERNAL LOADING CHARACTERISTICS

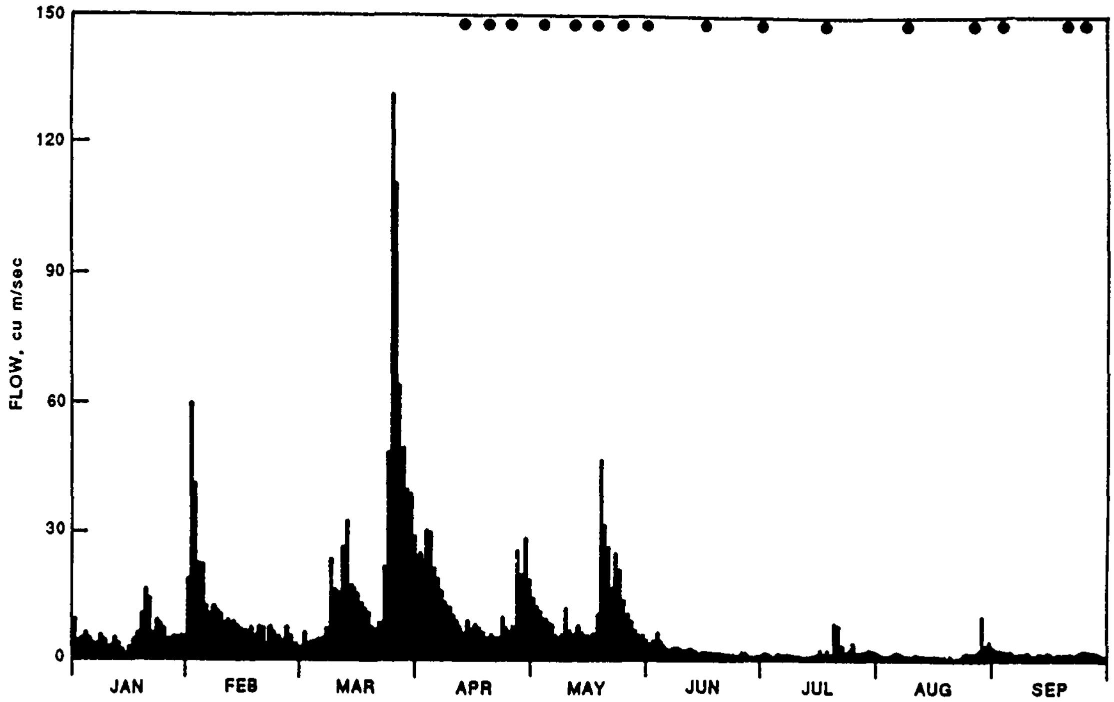
Mean daily inflows to Whitney Point Lake were obtained from a US Geological Survey stream gage upstream from the project on the Otselic River. At East Sidney Lake an upstream gage was not available and mean daily flows were calculated by NAB personnel using pool elevation and discharge relationships. Project personnel collected inflow samples for chemical analyses weekly during spring, high-flow periods and biweekly during low-flow periods.

Instantaneous total phosphorus and nitrogen loads (kg/day) were calculated for inflow samples by multiplying the observed concentration with the mean daily flow. Annual inflow loading rates (kg/yr) for total phosphorus and nitrogen were calculated with flow data from 1 October 1987 to 30 September 1988 and water quality data from 1 April to 30 September 1988 using FLUX (Walker 1987). Flows for Ouleout Creek and Handsome Creek were estimated at 75% and 25%, respectively, of the total inflow. Complete sampling and analytical methods are presented in Appendix A.

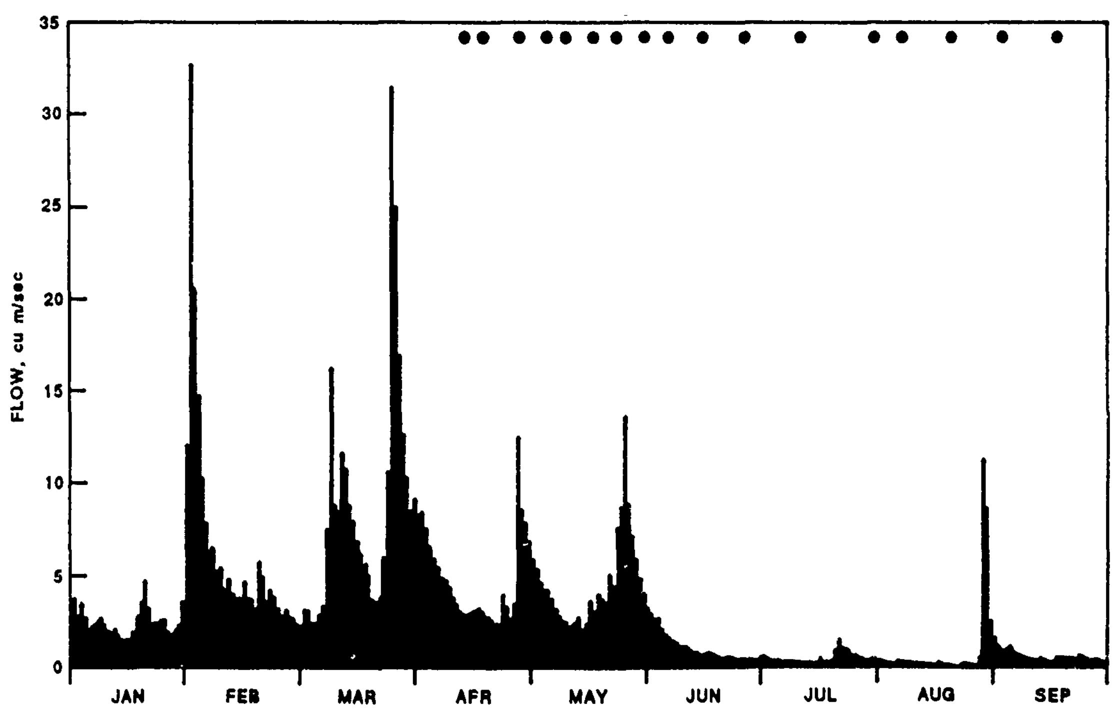
Inflow hydrographs for Whitney Point and East Sidney Lakes during the study period are depicted in Figure 6. Although 1988 was a low-precipitation year, several events of elevated flow occurred. Increased runoff was associated with snowmelt in February and March, and spring rains in April and May; low-flow conditions existed for the remainder of the study period (June through September). Discharge rates were similar to inflow rates except for mid to late April, when pool elevations were increased from winter pool levels to levels required for summer recreation.

Concentrations of total sodium, nitrogen, phosphorus, iron, and manganese are depicted in Figures 7, 8, and 9; concentration ranges and mean values are presented in Table 3. Although temporal changes in concentrations were not pronounced, varied concentrations of selected parameters were observed for the spring high flow period (May) and the summer low flow period. Concentrations of total sodium and nitrogen were lower during spring high flow events than during the summer low flow period. Conversely, total iron concentrations were higher during the spring high flows than during the summer low flow period.

Concentrations in Handsome Creek exhibited temporal patterns similar to those observed in Ouleout Creek, however mean concentrations of total sodium, nitrogen, and iron were lower than Ouleout Creek concentrations (Table 3). Differences between mean concentrations suggest that loading variations may



a. Whitney Point Lake



b. East Sidney Lake

Figure 6. Inflow hydrographs, January-September 1988
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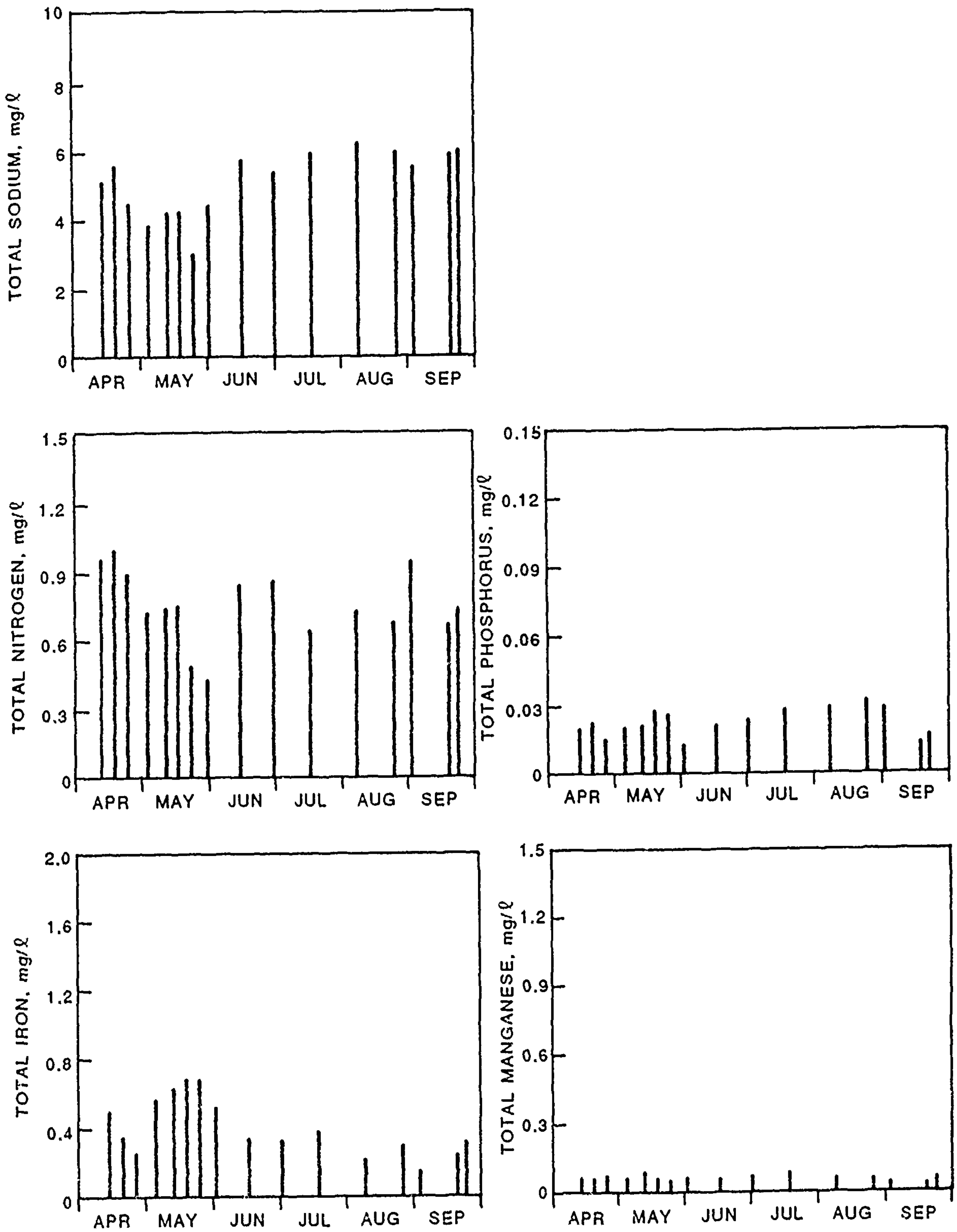


Figure 7. Inflow nutrient and metal concentrations, Otselic River, Whitney Point Lake, April-September 1988

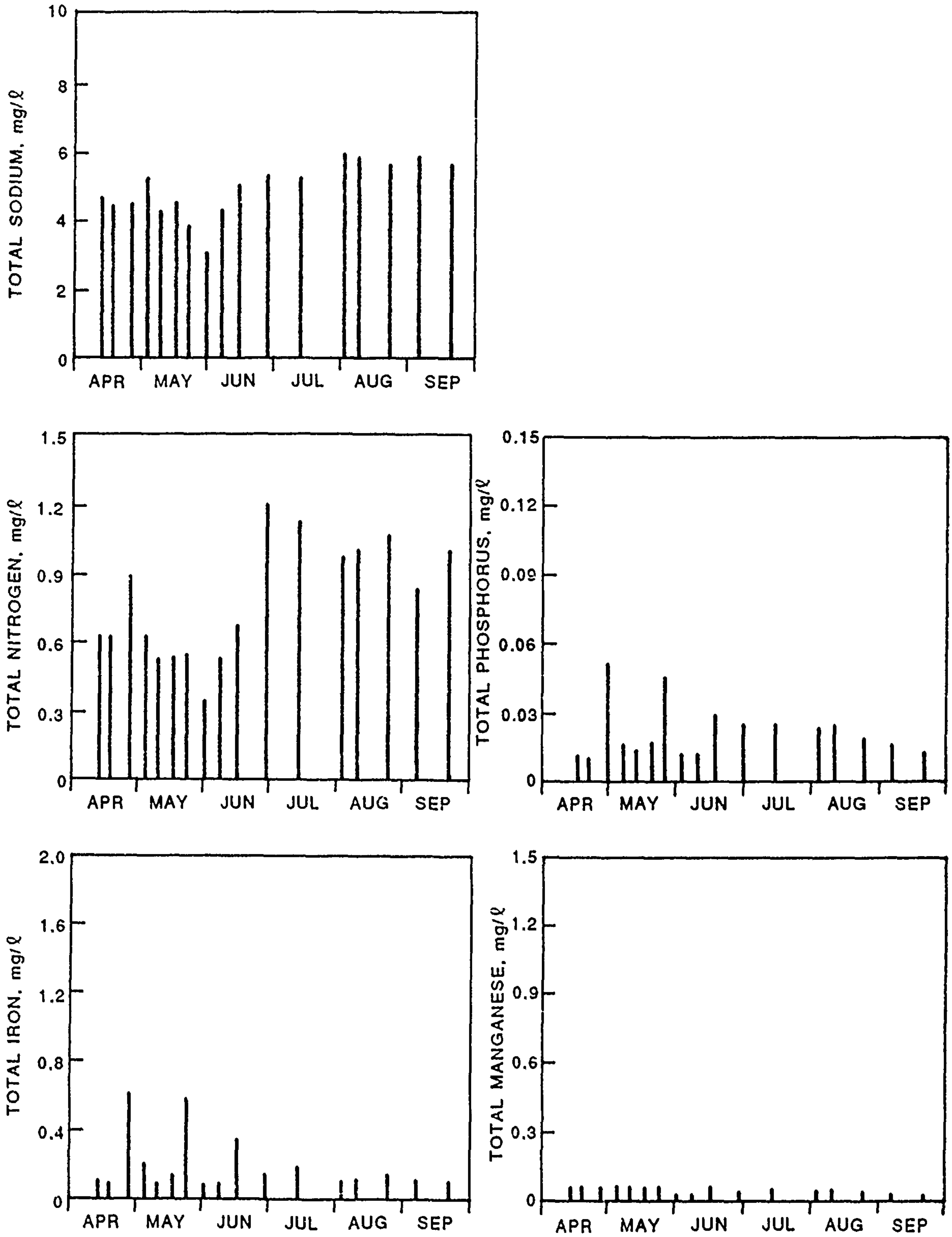


Figure 8. Inflow nutrient and metal concentrations, Ouleout Creek, East Sidney Lake, April-September 1988

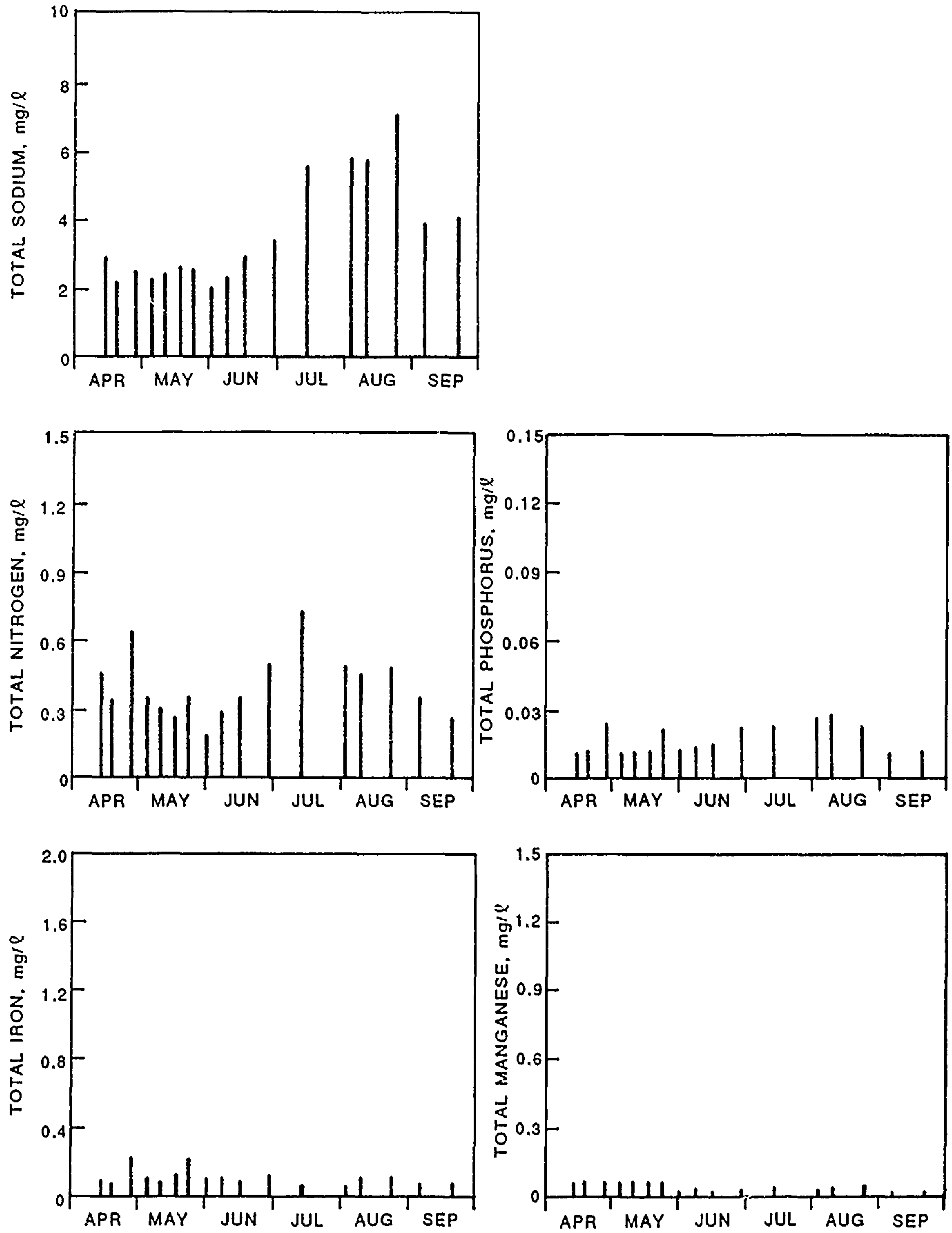


Figure 9. Inflow nutrient and metal concentrations, Handsome Creek, East Sidney Lake, April-September 1988

exist within sub-watersheds. Additional flow and chemical data from subwatersheds would be required for further assessment.

Maximum daily inflow loads were associated with hydrograph peaks and, in general, maximum inflow nutrient loads occurred in April and May (Figures 10 and 11). Nutrient loads during the summer growing season were lower and relatively stable.

Annual nutrient loading estimates for Whitney Point and East Sidney Lakes are reported in Table 4. For each project, total phosphorus loads were between 21 and 37 percent and total nitrogen loads were between and 38 and 64 percent of previous estimates (Kennedy et al. 1988). Different methods used in calculating nutrient loading may have contributed to observed differences in loading estimates. Loading estimates of Kennedy et al. (1988) employed indirect methods based on geographic comparisons and extrapolation from a single station where direct loading estimates were possible. Lack of concentration data during snowmelt and high flow events make interpretation and comparison of annual loading estimates difficult. Major peaks in water loads occurred in conjunction with snowmelt runoff, a period when nutrient concentrations are potentially higher than normal. Consequently, inadequate sampling during this period may result in low estimates of nutrient loading. Clearly, more detailed sampling during high flow periods is required for more accurate estimates of annual nutrient loading rates.

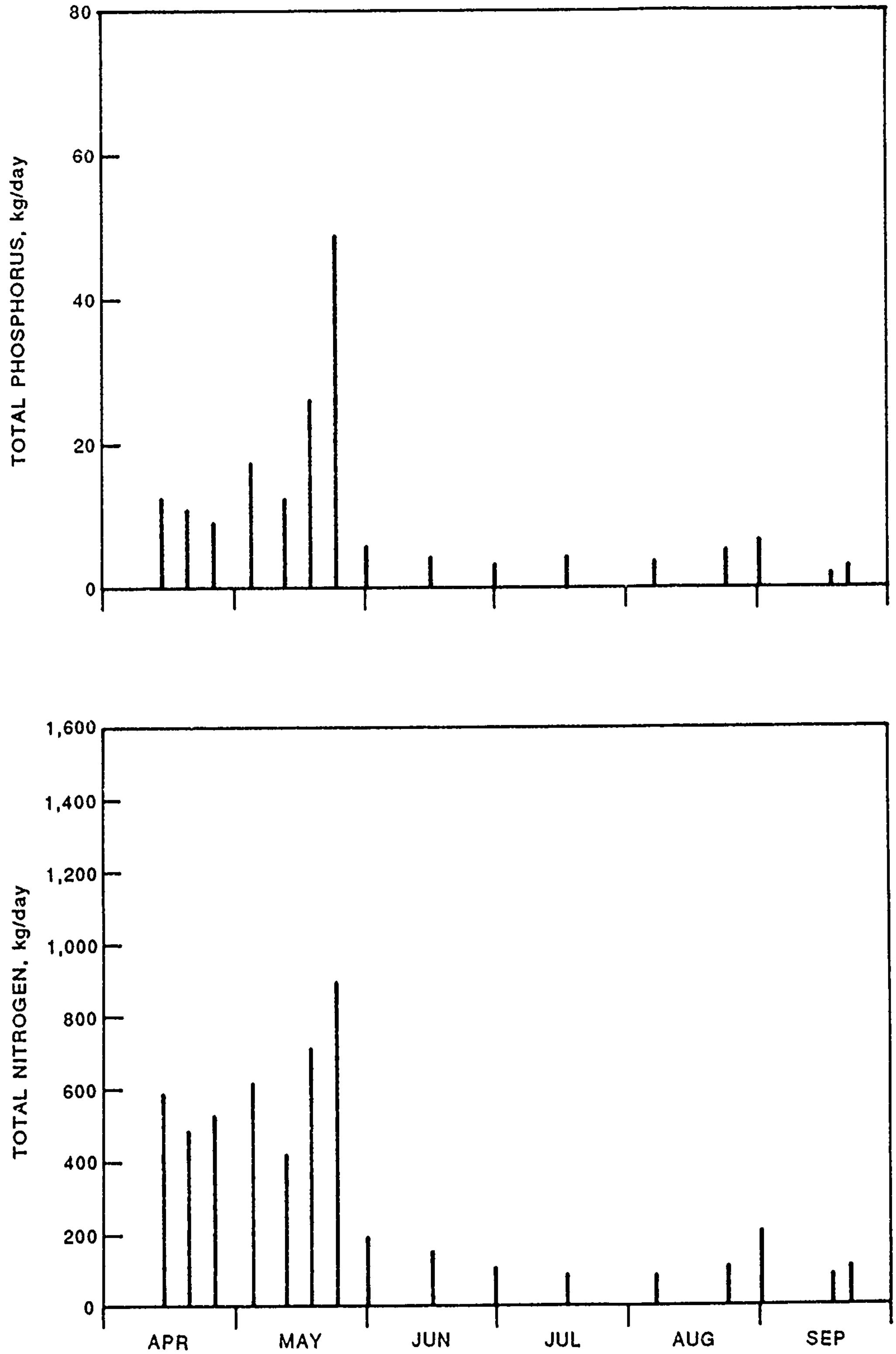


Figure 10. Instanteneous daily inflow nutrient loads, Otselic River, Whitney Point Lake, April-September 1988

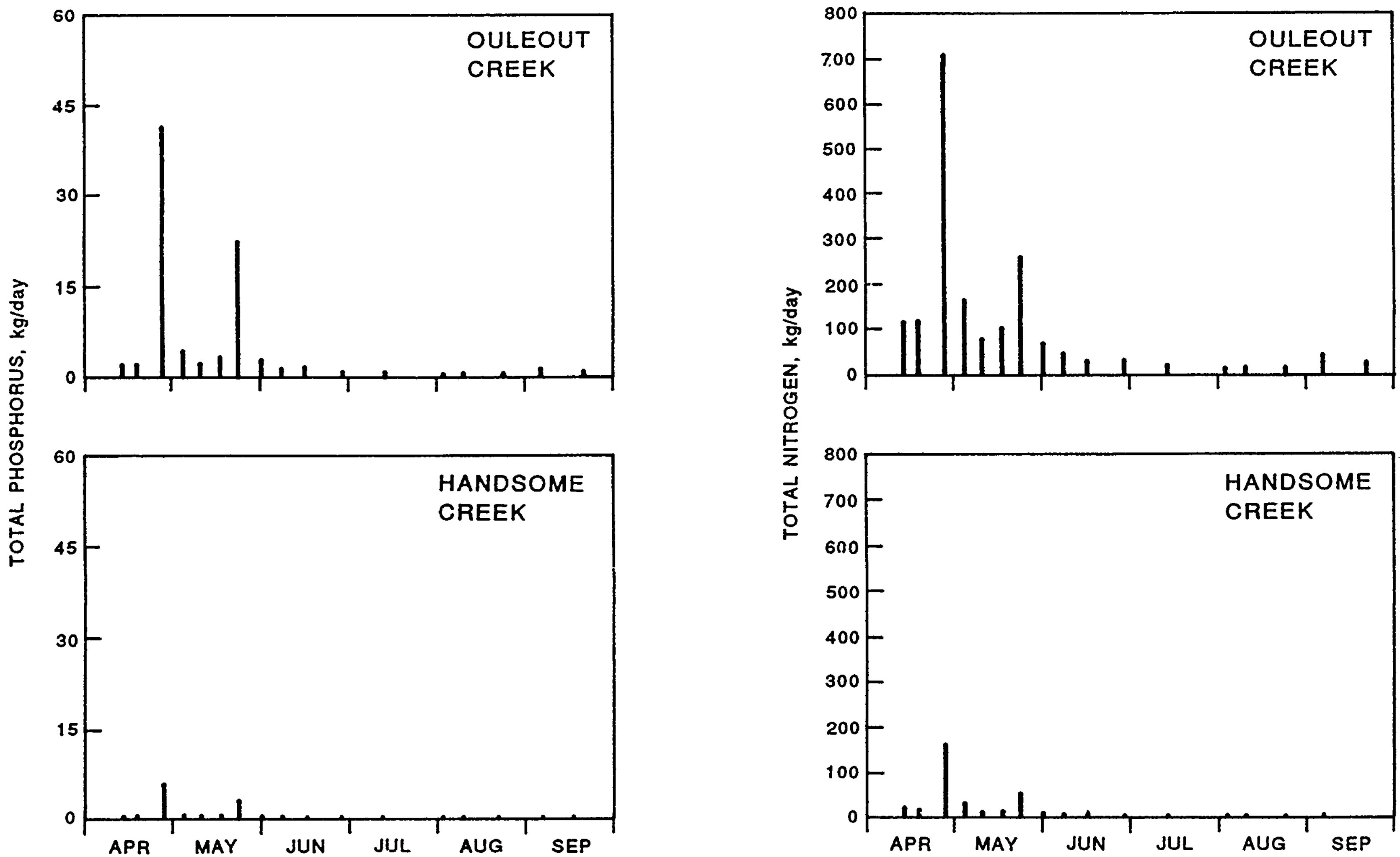


Figure 11. Instantaneous daily inflow nutrient loads, East Sidney Lake, April-September 1988

PART V: WATER QUALITY ASSESSMENT

Water quality sampling was conducted six times throughout the summer growing season to define seasonal development of physicochemical gradients in the lakes. Sampling stations were located upstream from the dam at the deepest point in each lake. Temperature, dissolved oxygen concentration, and specific conductivity were measured at one-meter intervals from surface to near bottom. Water samples for chemical analyses were collected at surface, mid-depth, and near-bottom. Integrated samples for biological analyses were collected from the mixed surface layer.

Samples for chemical analyses were preserved upon collection for subsequent analyses. Biological samples were split and one portion was processed for chlorophyll a analysis and the remainder was preserved for phytoplankton identification. Complete sampling and analytical methods are presented in Appendix A.

Temperature and Dissolved Oxygen

Thermal gradients at Whitney Point Lake were first observed in early June as surface temperatures increased from 14 degrees C in May to near 20 degrees C in early June (Figure 12). Bottom temperatures increased from 10 degrees C to 16 degrees C during this same time period, and a distinct thermocline developed at a depth of 4 to 5 meters. Thermal gradients were not observed in late June when temperatures were near 20 degrees C throughout the water column. Isothermal conditions coincided with a period of increased wind, suggesting wind induced mixing of the water column.

Thermal gradients were re-established by mid July, as surface temperatures increased to near 24 degrees C, while bottom temperatures remained near 20 degrees C. Surface and bottom temperatures continued to increase from mid July to early August and weakly stratified conditions, possibly a result of increasing bottom temperatures, were present until late August. By late August, surface temperatures had decreased sufficiently for mixing to occur.

Temperatures in East Sidney Lake increased from approximately 8 degrees C in early May to nearly 16 degrees C by mid June but thermal gradients were not apparent (Figure 13). A thermocline at a depth of 5-6 meters was observed by late June, however, as surface temperatures increased to near 21 degrees C and bottom temperatures remained near 16 degrees C. Thermal gradients were

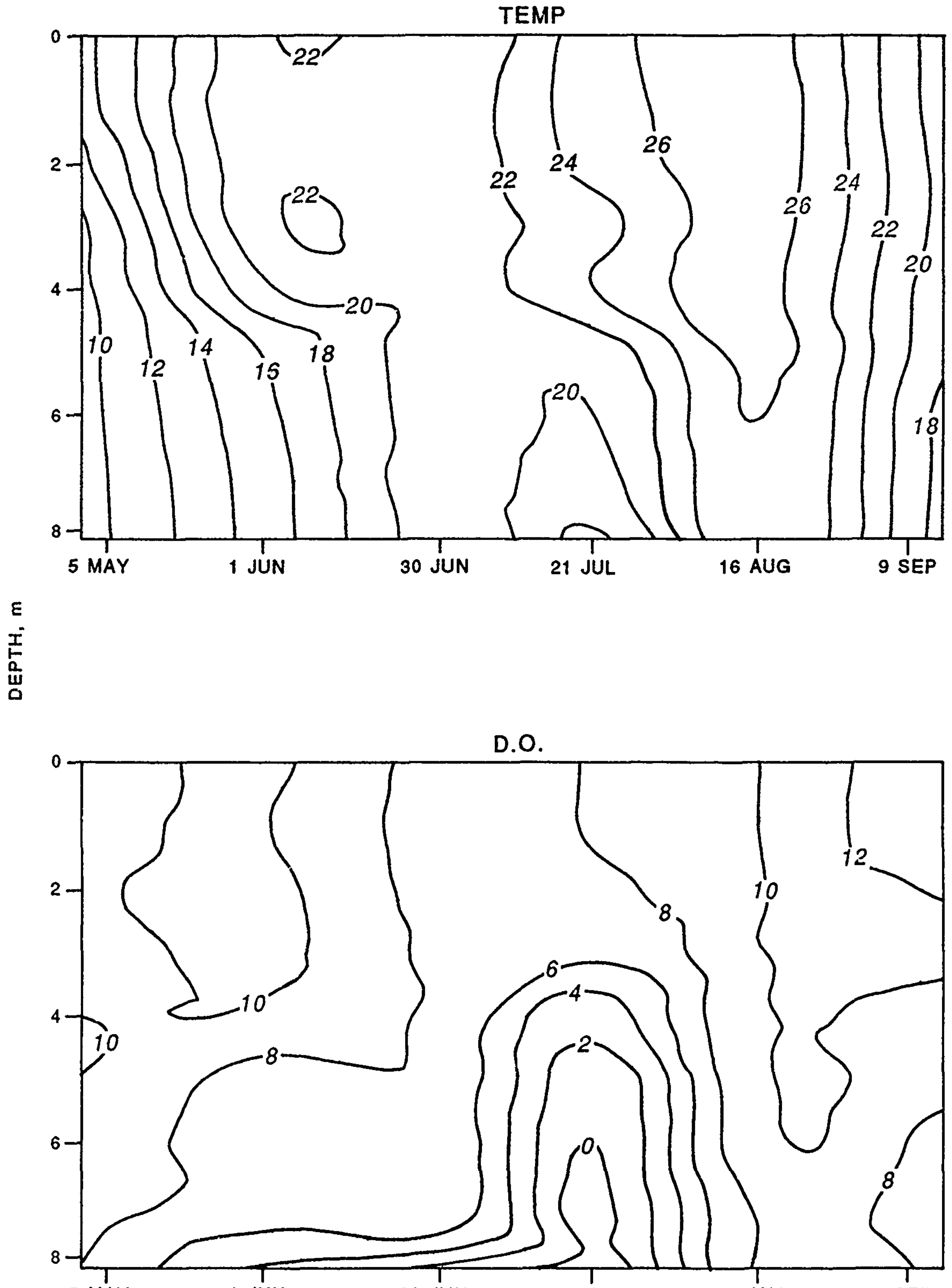


Figure 12. Vertical and temporal distribution of temperature (top) and dissolved oxygen (bottom) in Whitney Point Lake, 5 May through 9 September 1988

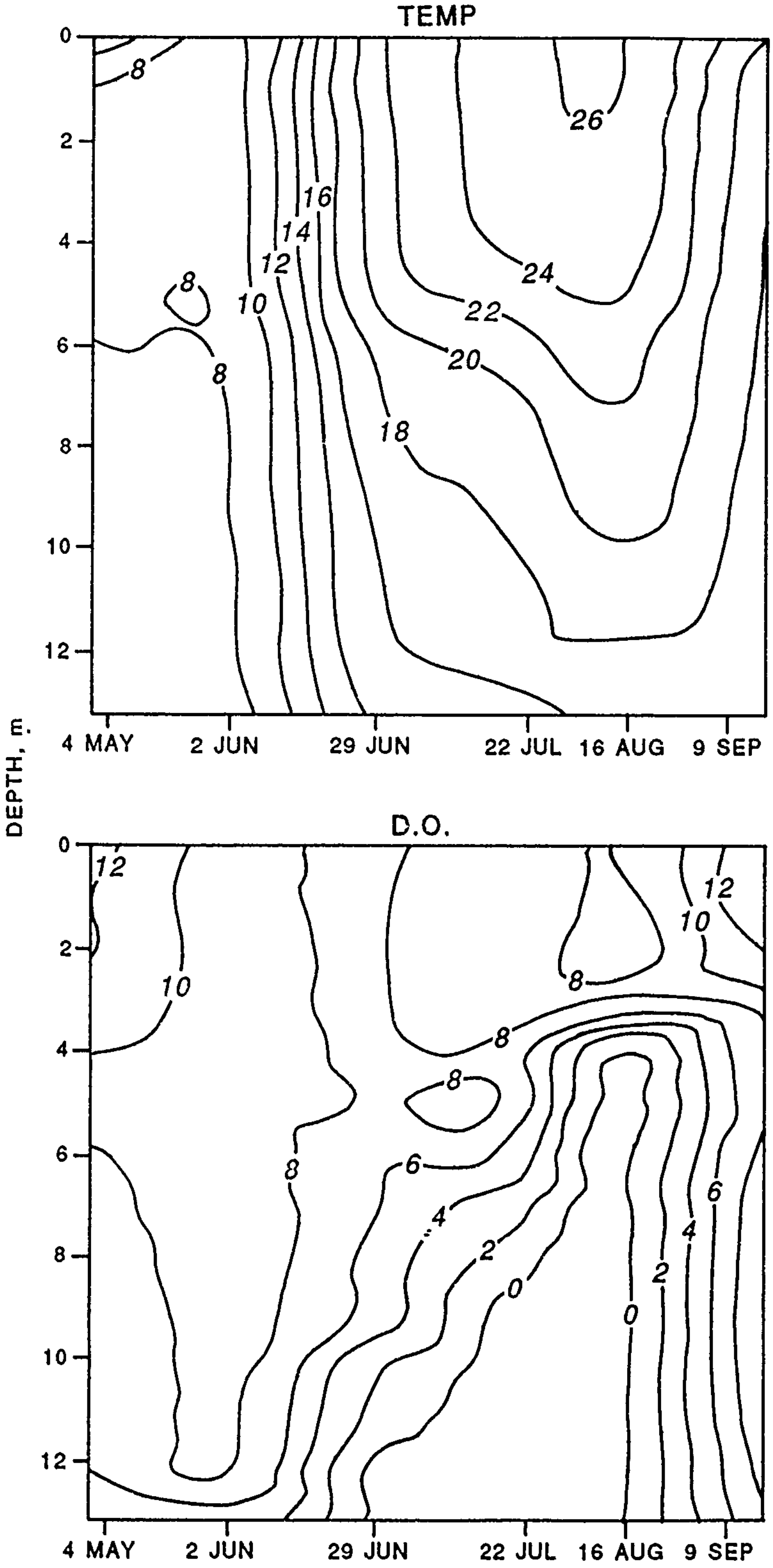


Figure 13. Vertical and temporal distribution of temperature (top) and dissolved oxygen (bottom) in East Sidney Lake, 4 May-9 September 1988

well established by July, however, and the thermocline had expanded to a depth between 4 and 7 meters. Weakly stratified conditions were present until late August when autumnal mixing occurred. Contrary to observations at Whitney Point Lake, intermittent mixing of the water column was not observed at East Sidney Lake during the study period.

Kennedy et al. (1988) described the thermal structure of Whitney Point and East Sidney Lakes in terms of thermal stability (a measure of a lake's resistance to mixing) and concluded that Whitney Point Lake was subject to intermittent mixes due to low thermal stability. East Sidney Lake displayed higher thermal stability and was therefore less susceptible to mixing.

Thermal stability values for the six sample dates reported here (Table 5) were calculated using equations from Hutchinson (1957). At Whitney Point Lake, thermal stability remained below 10 g-cm/sq cm throughout the study period, suggesting that minimum energy input would be required to mix the lake. Indeed, following the mixing event in late June, thermal stability was reduced to nearly 0.0 g-cm/sq cm. Even though temperature gradients again established after the mixing event, thermal stability was low for the remainder of the study period.

East Sidney Lake experienced higher values for thermal stability, however, observed values less than 10-15 g-cm/sq cm indicate periods of low stability and potential for intermittent mixing. While low in early summer, thermal stability increased in late June coincident with the onset of thermal stratification. Peak stability occurred in mid July at the height of thermal stratification.

Patterns in thermal stability in the two lakes are attributable to outlet structure and operation, basin morphometry, and environmental factors. The removal of colder bottom water during the stratified period, due to bottom withdrawal operations, increases heat gain throughout the water column. Decreased hydraulic residence time of bottom waters, as dictated by hypolimnetic volume and discharge rate, also increases heat gain in bottom waters. Additionally, effects of thermal input are more pronounced in shallow systems with small hypolimnia in that heat gain in bottom waters increases as mean depth and hypolimnetic volume decrease. Heat gain in the hypolimnion is also a function of hypolimnetic surface area and depth, each of which are a function of basin morphometry. As a consequence of release operations and morphometric characteristics, temperature gradients, which contribute to density gradients, are less defined and thermal stability is reduced. Periods of

increased wind, decreased temperatures, or a combination of both may provide sufficient energy to partially or completely mix the system.

Thermal stability at East Sidney Lake was greater than that of Whitney Point Lake, reflecting differences in factors contributing to thermal stability at the projects. Whitney Point Lake is more shallow, exhibits a shorter hydraulic residence time, and has a larger surface area than East Sidney Lake. Lower surface-to-volume ratio, greater mean depth, and a more-defined thermal structure at East Sidney Lake may contribute to greater thermal stability values than that observed for Whitney Point Lake. Additionally, East Sidney Lake is less subject to direct influence of prevailing winds than is Whitney Point Lake.

Changes in thermal structure and stability clearly influenced dissolved oxygen concentrations at Whitney Point Lake. Prior to the onset of thermal stratification, dissolved oxygen concentrations in bottom waters ranged from 8 to 10 mg/l (Figure 12). As thermal gradients developed in early June, dissolved oxygen concentrations in bottom waters decreased. However, dissolved oxygen concentrations were near 7 mg/l throughout the water column in late June, when near isothermal conditions were observed following an apparent mixing event.

Dissolved oxygen gradients intensified coincident with the return of thermal stratification in mid July. Anoxic conditions were observed in the hypolimnion in mid to late July and persisted until the early August mixing event. Following autumnal turnover in late August, dissolved oxygen concentrations increased to 8 to 10 mg/l throughout the water column.

Dissolved oxygen concentrations in East Sidney Lake reflected a more stable thermal structure (Figure 13). Prior to stratification concentrations were near 8 to 10 mg/l; however, concentration gradients were quickly established following development of thermal stratification. Surface concentrations remained near 8 mg/l, while concentrations below the thermocline declined rapidly. Anoxic conditions were observed in the hypolimnion in late June, and persisted until late August. For much of August, anoxic conditions were within 4 meters of the surface. After turnover, dissolved oxygen concentrations increased to 10 mg/l throughout the water column.

The rate at which dissolved oxygen decreases in the hypolimnia of stratified lakes provides an indicator of the amount of organic material available for decomposition (Wetzel 1983). Calculation of this rate (termed hypolimnetic oxygen depletion rate or HOD) assumes isolation of bottom waters due to

density stratification. Data describing changes in dissolved oxygen concentrations from the onset of thermal stratification until the date of minimal concentrations is required for calculation of the HOD. These rates may be expressed on areal or volumetric basis. Areal rates allow comparison with primary productivity rates since the units are similar, while volumetric rates can be expressed in terms of concentration changes.

Oxygen depletion rates for East Sidney and Whitney Point Lakes were calculated using the computer program PROFILE (Walker 1987). For Whitney Point Lake, calculations were limited to the period between the first two samplings (5 May to 1 June) due to the mixing event in late June. Based on temperature and dissolved oxygen profiles on 1 June, elevations of 293 m NGVD and 291 m NVGD were used as boundaries for the top of the metalimnion and hypolimnion, respectively. The metalimnion, which includes the thermocline, is defined as the layer between surface and bottom waters where temperature changes with depth are most pronounced. Areal and volumetric depletion rates were 80.6 and 49.7 mg/sq m per day and 106.5 and 47.9 mg/cu m per day for the hypolimnion and metalimnion, respectively. Combined rates for the metalimnion and hypolimnion were 64.1 mg/sq m per day and 54.7 mg/cu m per day. The latter corresponds to an average decline in dissolved oxygen concentration of 0.05 mg/l per day.

Higher depletion rates were calculated for Whitney Point when data for the period 30 June to 21 July were employed in the calculation. While dissolved oxygen concentrations in bottom waters were below 0.5 mg/l, and thus, undesirably low for such a calculation, this period was less confounded by mixing events. The volumetric and areal rates for the combined volume of the metalimnion and hypolimnion were 237.7 mg/sq m per day and 279.1 mg/cu m per day, respectively. The latter corresponds to an average decline in dissolved oxygen concentration of 0.3 mg/l per day. Clearly, these are conservative estimates of the actual rates since dissolved oxygen is reintroduced into the hypolimnion during mixing events.

Oxygen depletion rates for East Sidney Lake were computed for the period between early May and late June. Based on temperature and dissolved oxygen profiles on 29 June, elevations of 346 m NGVD and 339 m NGVD were used as boundaries for the top of the metalimnion and hypolimnion, respectively. Areal and volumetric depletion rates were 358.6, 360.8, and 385.8 mg/sq m per day and 226.4, 109.7, and 113.5 mg/cu m per day for the hypolimnion, metalimnion and the combined volume below 346 m NGVD, respectively. A decline in

dissolved oxygen concentration of 0.4 mg/l per day compares well with the value for Whitney Point Lake.

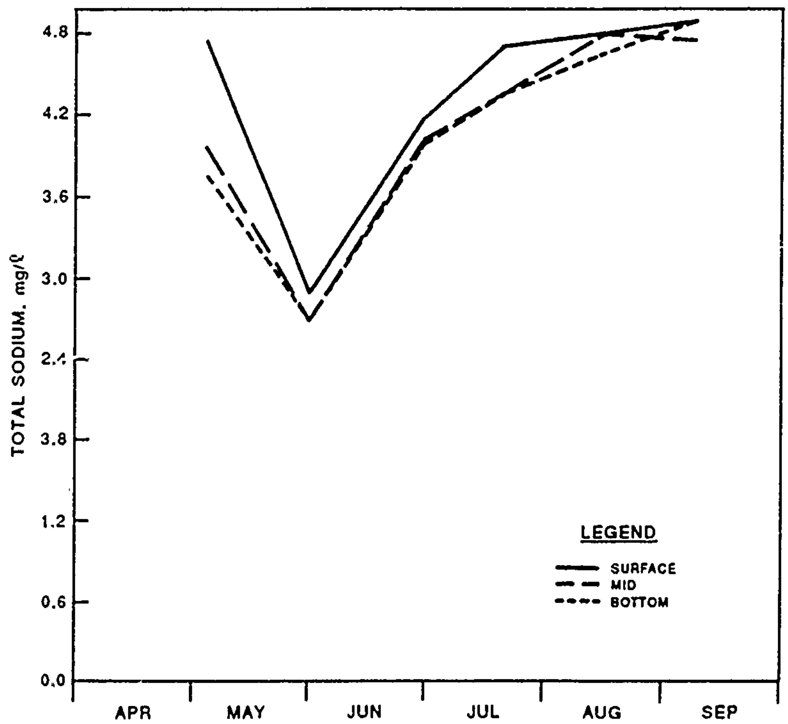
Oxygen depletion rates calculated for 1988 are well within the range expected for eutrophic lakes (Hutchinson 1957) and in good agreement with rates calculated for previous periods by Kennedy et al. (1988). The degree to which mixing events reaerate portions of the water column is unknown; however, such events are clearly not uncommon. In the absence of such events, periods of anoxia would be expected to be of longer duration and potentially involve a greater volume of the lake. The importance of oxygen depletion in the recycling of material is discussed later in this Part.

Metal and Nutrient Cycling

Specific conductance ranged from 80 to 180 micromhos/cm with highest values observed coincident with anoxia. A measure of the ability of a fluid to conduct electrical current, specific conductance is a relative indication of dissolved chemical concentrations. Higher specific conductance values, observed in anoxic bottom waters suggest an increase in concentrations of dissolved chemical constituents.

Total sodium concentrations, which were measured to provide a conservative tracer for description of chemical behavior during the study period, are presented in Figure 14. A conservative constituent is not significantly affected by physical, chemical, or biological processes and any changes in concentration are therefore assumed to be due to changes in input quality. Decreased sodium concentrations were observed in both lakes in early June. While a clear explanation was not readily apparent, the May high flow event may have resulted in dilution. Concentrations gradually increased from near 2.8 mg-Na/l in early June to near 4.8 mg-Na/l by the end of the study period. Inflow concentrations were between 5.3 and 6.2 mg-Na/l (Otselic River) and 4.2 and 5.7 mg-Na/l (Ouleout Creek) during June through early September and may have contributed to observed in-lake concentration increases. Mechanisms for observed inflow concentration increases of sodium throughout the summer were not readily apparent.

Concentrations of total iron and manganese were higher in bottom waters than in mid and surface waters during the study period (Figure 15 and 16). Total iron and manganese concentration maxima (1.9 mg-Fe/l and 1.0 mg-Mn/l) at Whitney Point Lake were observed in late July, coincident with anoxia. Total



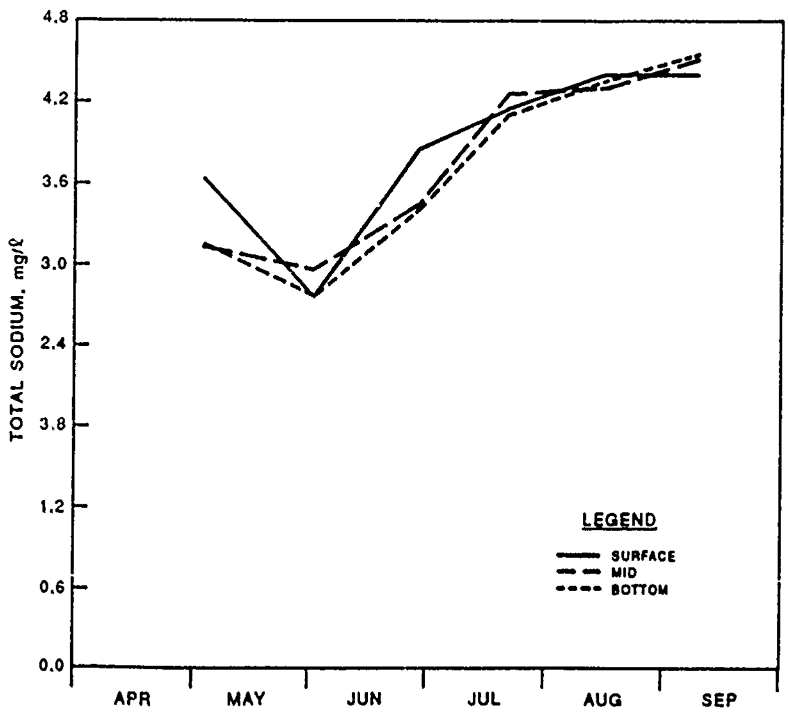


Figure 14. Temporal and vertical distribution of total sodium in Whitney Point (top) and East Sidney (bottom) Lakes, May-early September 1988

iron concentrations were higher in the hypolimnion than at surface or middepth throughout the study period. With the exception of increased concentrations observed in July, total manganese concentrations remained relatively low throughout the water column during the study period.

At East Sidney Lake, hypolimnetic concentrations of iron ranged from 0.25 to 2.33 mg-Fe/l; manganese concentrations ranged from 0.07 to 1.28 mg-Mn/l. Maximum observed concentrations occurred in bottom depth samples during June, July, and August. Total iron and manganese concentrations remained relatively low at mid-depth and in surface waters during the study period.

Total phosphorus concentrations at Whitney Point Lake ranged from 0.017 to 0.033 mg-P/l in May and increased to 0.045 to 0.075 mg-P/l in September (Figure 17). The mean concentration at surface during the growing season (June through mid-August) was 0.036 mg-P/l. Minor vertical gradients were observed with a general tendency of increased concentration with depth. A dissimilar trend was observed immediately after the mixing event in late June, at which time bottom water concentrations were lower than mid-depth and surface concentrations. However, concentrations increased in bottom waters coincident with the decrease in dissolved oxygen concentration and vertical gradients were again observed during anoxic conditions in July.

At East Sidney Lake, total phosphorus concentrations ranged from 0.011 to 0.018 mg-P/l in May and increased to 0.021 to 0.169 mg-P/l in August (Figure 18). A mean concentration of 0.024 mg-P/l was observed in the mixed, surface layer during the growing season. Increased concentrations in bottom waters during the stratified period resulted in observed vertical gradients. Maximum observed concentrations occurred coincident with anoxic conditions. Concentrations in the surface waters were less variable than bottom water concentrations although increases in surface waters were apparent July through early September.

Increased hypolimnetic phosphorus concentrations during stratification indicate an internal source of phosphorus, the sediments. Complex chemical and biological mechanisms provide for the mobilization and release of phosphorus from the sediments (Holdren and Armstrong 1980 and Bostrom 1984, for example). Once released, soluble phosphorus is transported in the hypolimnion via advection and diffusion. Concentration increases under sustained anoxia, i.e., phosphorus accumulation, will be dependent upon sediment concentrations. Accumulation of soluble phosphorus in the hypolimnion, as a result of internal

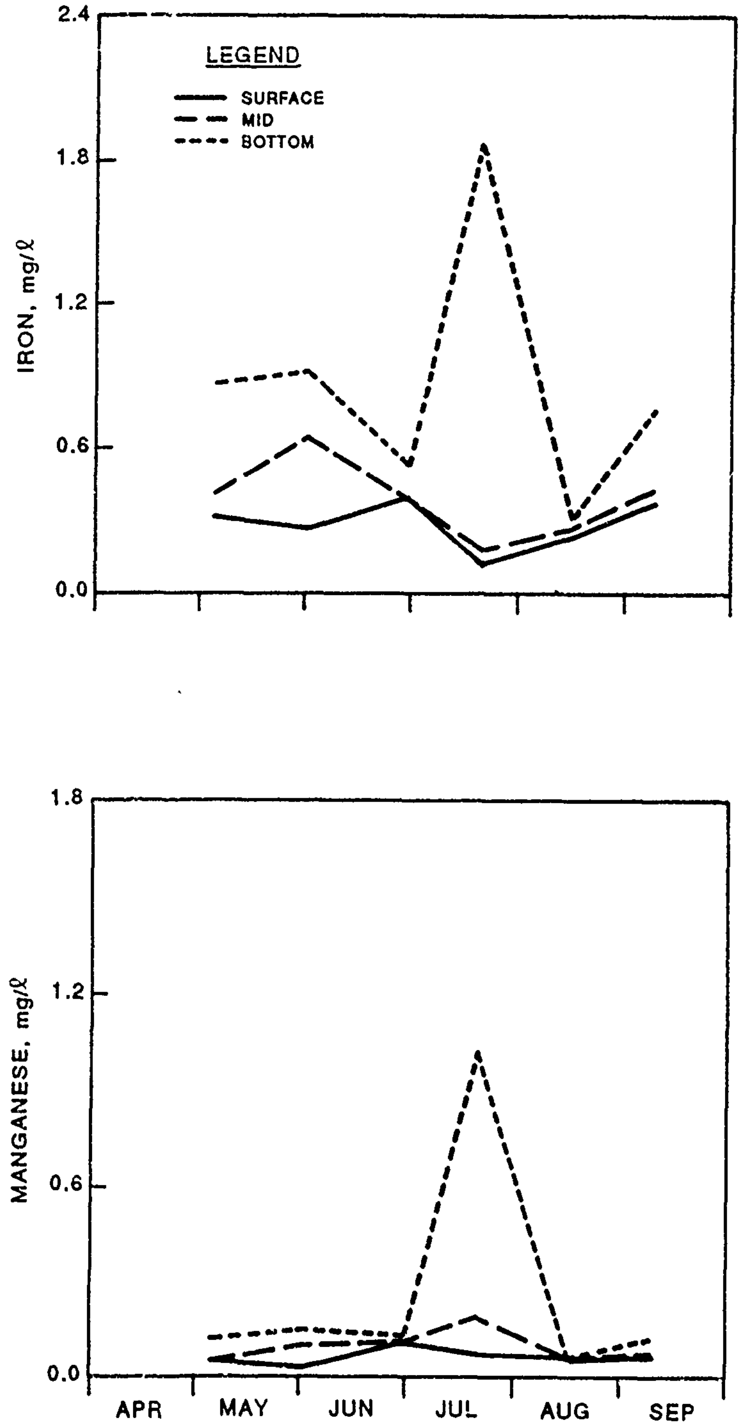


Figure 15. Temporal and vertical distribution of total iron and manganese in Whitney Point Lake, May-early September 1988

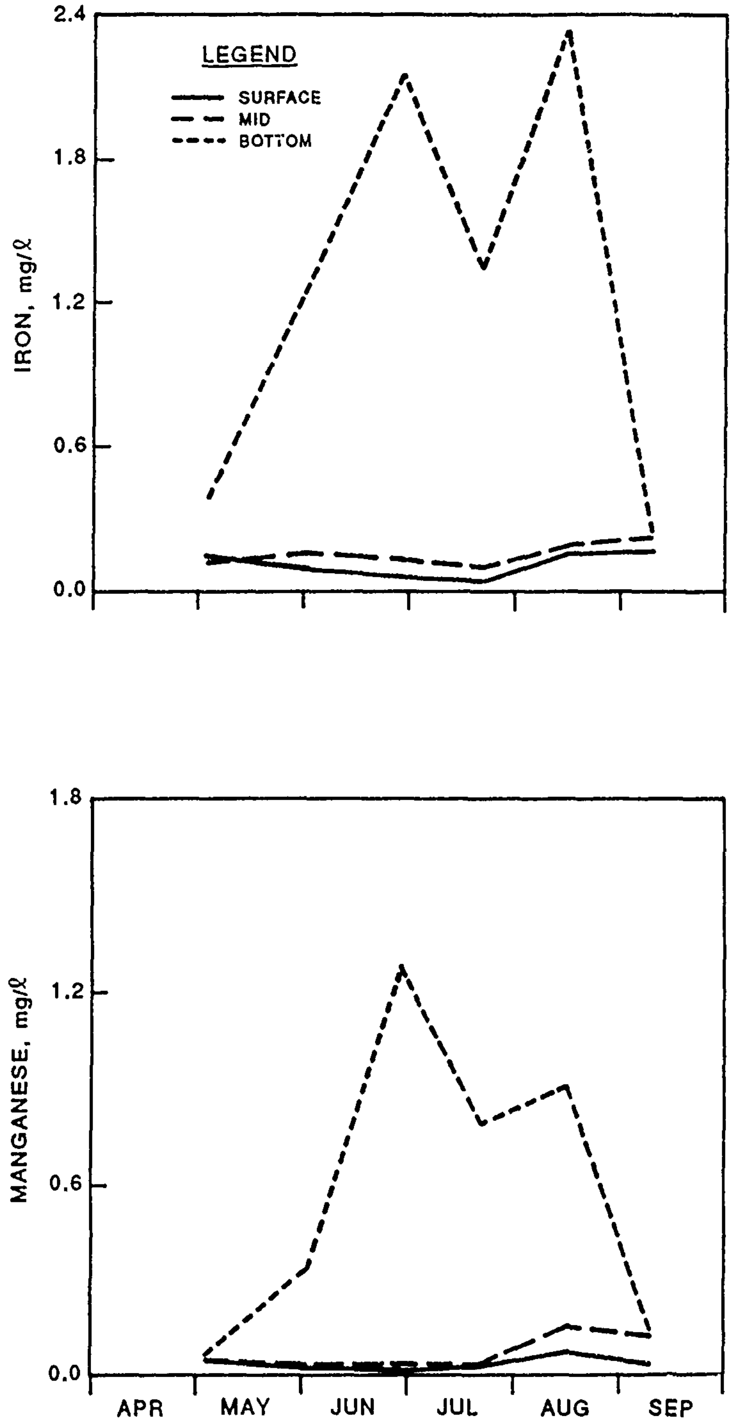


Figure 16. Temporal and vertical distribution of total iron and manganese in East Sidney Lake, May-early September 1988

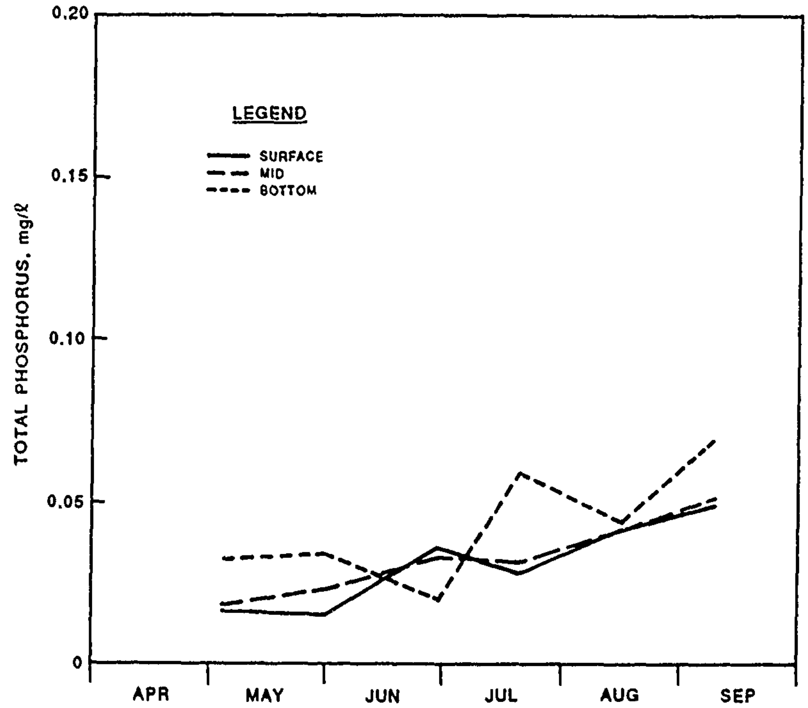


Figure 17. Temporal and vertical distribution of total phosphorus in Whitney Point Lake, May-early September 1988

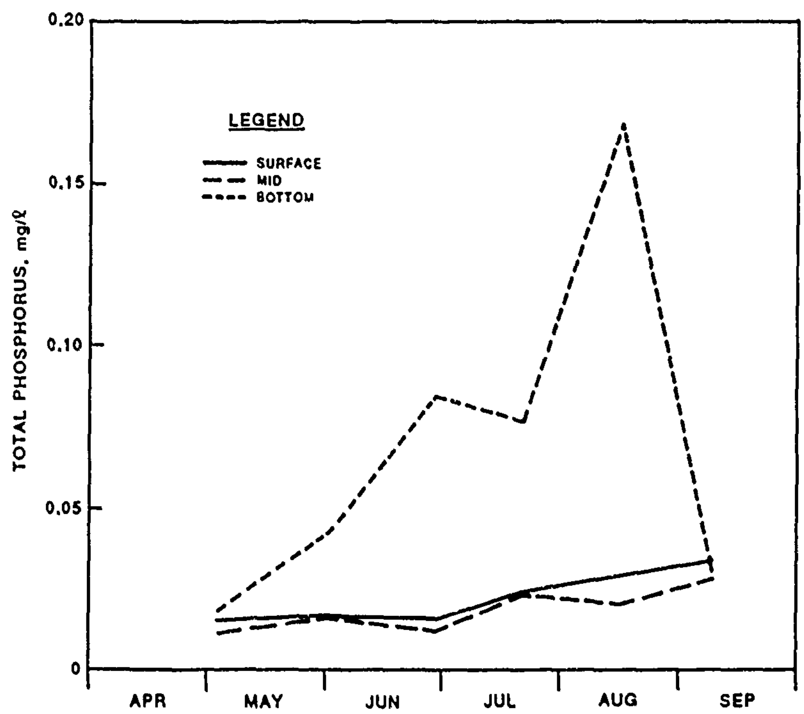


Figure 18. Temporal and vertical distribution of total phosphorus in East Sidney Lake, May-early September 1988

loading, may impact phytoplankton productivity in the surface waters should hypolimnetic phosphorus become available to epilimnetic phytoplankton **via** physical processes such as wind-induced mixing.

Total nitrogen concentrations at Whitney Point Lake displayed little variation throughout the study period (Figure 19). A mean concentration of 0.71 mg-N/l was observed in the surface waters during the growing season. The increased nitrogen concentration observed in late July (1.11 mg-N/l) coincided with anoxia and may be attributed to accumulation of ammonia mobilized from the sediments via reduction, solubilization, and diffusion. Decreased bacterial nitrification during anoxia may have contributed to the increased accumulation of ammonia as well.

At East Sidney Lake, total nitrogen concentrations exhibited temporal and vertical patterns similar to those observed for total phosphorus (Figure 20). Concentration increases were most apparent in bottom waters coincident with decreases in dissolved oxygen concentration. Maximum observed concentrations may be attributed to increased ammonia concentrations due to chemical and biological processes as described above. Pronounced concentration increases were observed in the surface waters in late June and early September. A general tendency of increased concentrations in surface waters was observed from late June through early September. Although no clear mechanism for this trend was apparent, fixation of atmospheric nitrogen by phytoplankton and increased inflow concentrations (perhaps related to summer land use practices or effects of low flow), are possible sources for observed concentration increases.

The occurrence and significance of internal materials loading is suggested by evaluation of phosphorus budgets. In-lake phosphorus concentrations increased while inflow phosphorus concentrations remained relatively constant during the summer stratified period, suggesting internal loading of phosphorus. Internal loading of phosphorus and nitrogen was calculated for the summer growing season using a mass balance equation:

$$(L)int = (X)chng - \{(X)in - (X)out\}$$

where

(L)int = net internal load (kg)
(X)chng = change in storage (kg)
(X)in = external load (kg)
(X)out = loss due to discharge (kg)

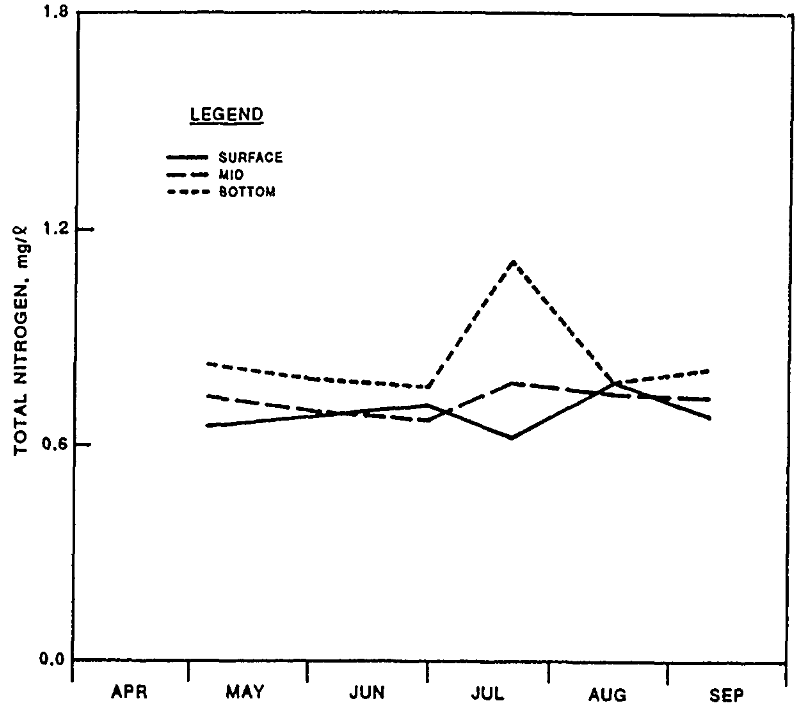


Figure 19. Temporal and vertical distribution of total nitrogen in Whitney Point Lake, May-early September 1988

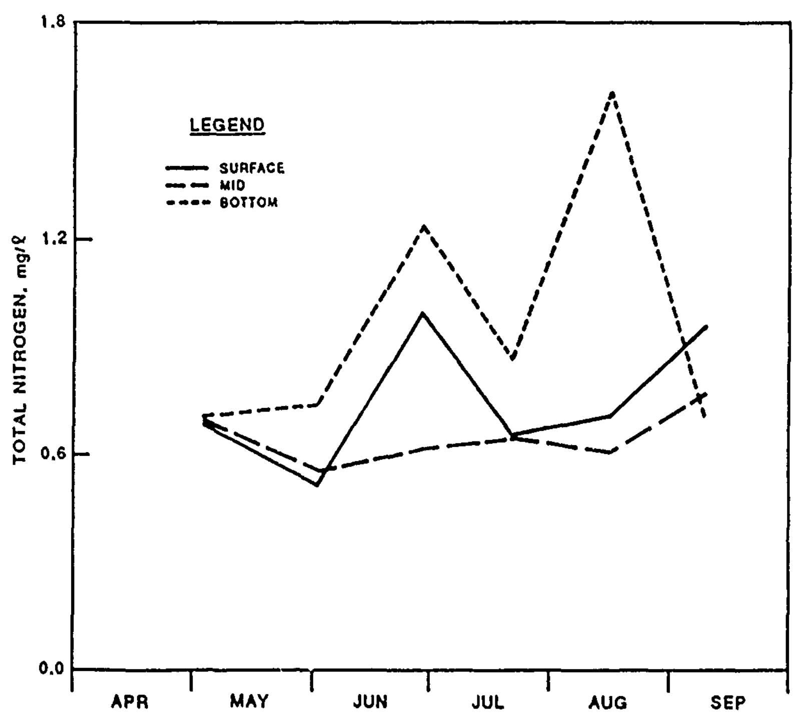


Figure 20. Temporal and vertical distribution of total nitrogen in East Sidney Lake, May-early September 1988

Growing season loading estimates and loading rates for total phosphorus, nitrogen, and total sodium are presented in Tables 6 and 7, respectively. Mass balance calculations for total sodium, which provide an estimate of error by assuming sodium to be conservative, suggest that estimates of internal phosphorus loadings are relatively accurate and substantive. While internal loads, and therefore error, for total sodium were less than 10% of the total load, internal loading of total phosphorus accounted for 60 and 70% of the total phosphorus load during the growing season at Whitney Point and East Sidney Lakes, respectively. Internal nitrogen loading, on the other hand, accounted for only 10 to 20% of the total load at each lake during the same period. These values, similar to those of total sodium, suggest that net internal loading of nitrogen is minimal.

Of significance is the considerable contribution of internal phosphorus loading at the projects. Concentration profiles in Whitney Point Lake, following the mixing event in June, indicate exchange between bottom and surface waters, thereby increasing phosphorus availability to epilimnetic phytoplankton when external loading is low. As a consequence of pronounced internal phosphorus loading, reductions in external phosphorus loading may have minimal impact on phytoplankton productivity during the growing season.

Phytoplankton Dynamics

Measurements of chlorophyll concentration provide an indirect measure of phytoplankton biomass. Since chlorophyll pigments occur in all organisms capable of photosynthesis, increases in chlorophyll concentrations (inferred from concentrations of the major pigment, chlorophyll *a*) suggest increases in phytoplankton population size. Chlorophyll *a* concentrations exhibited marked trends in both lakes (Figures 21 and 22). Concentrations, while near or below 10 μg/l in early summer, increased to near 30 and 40 μg/l in Whitney Point Lake and near 20 to 30 μg/l in East Sidney Lake in mid to late summer. Increased chlorophyll *a* concentrations, coincident with increased hypolimnetic nutrient concentrations, suggest a direct relationship between internal nutrient loading and phytoplankton productivity.

The atomic ratio of nitrogen-to-phosphorus is often used as an indicator of nutrient status (i.e., which nutrient may be limiting productivity, nitrogen or phosphorus), phytoplankton productivity, and community structure. Sakamoto (1966) suggested that ratios less than 10 indicated nitrogen

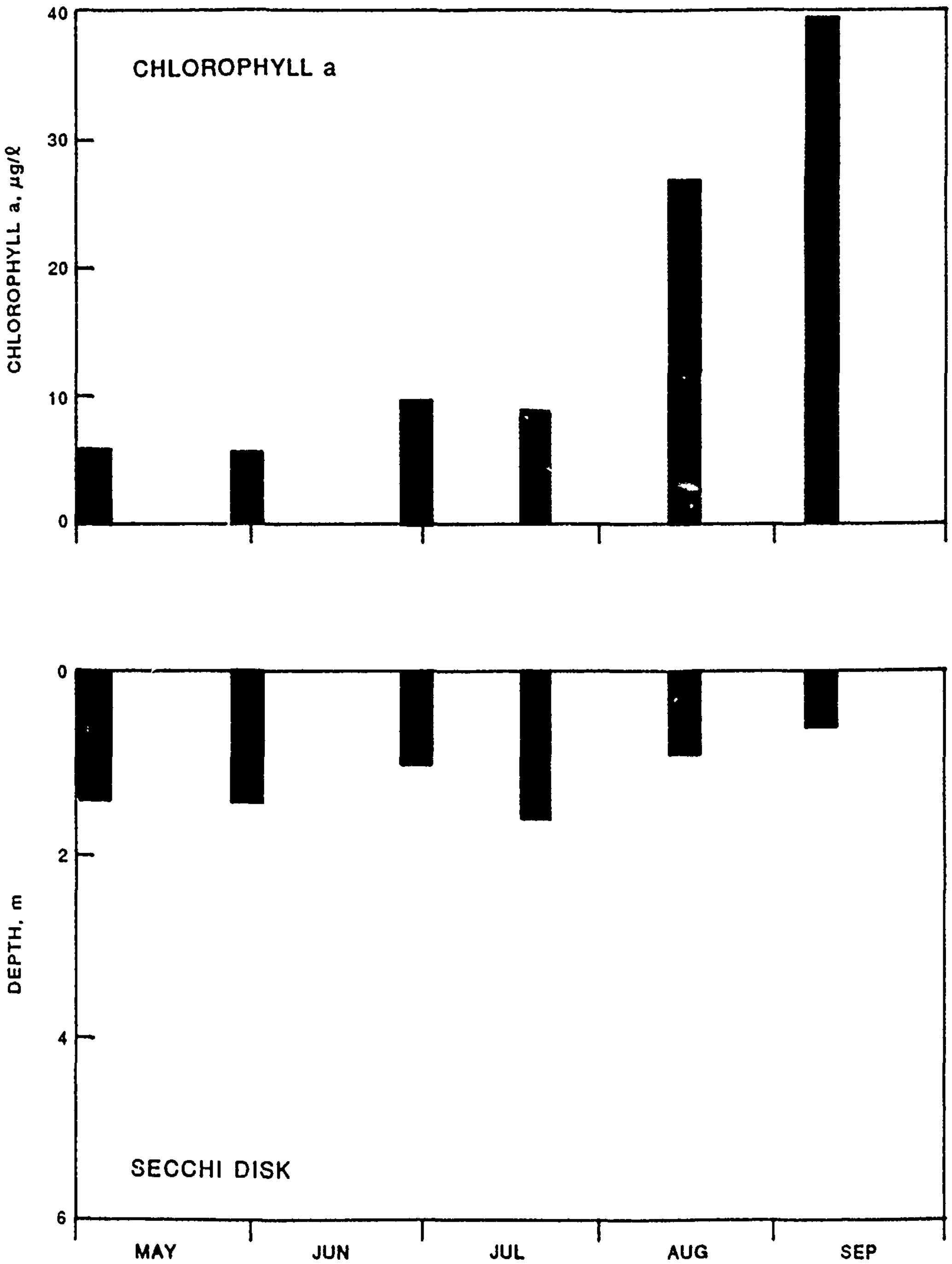


Figure 21. Temporal distribution of chlorophyll a concentrations (top and Secchi disk depths (bottom) in Whitney Point Lake, May-early September 1988

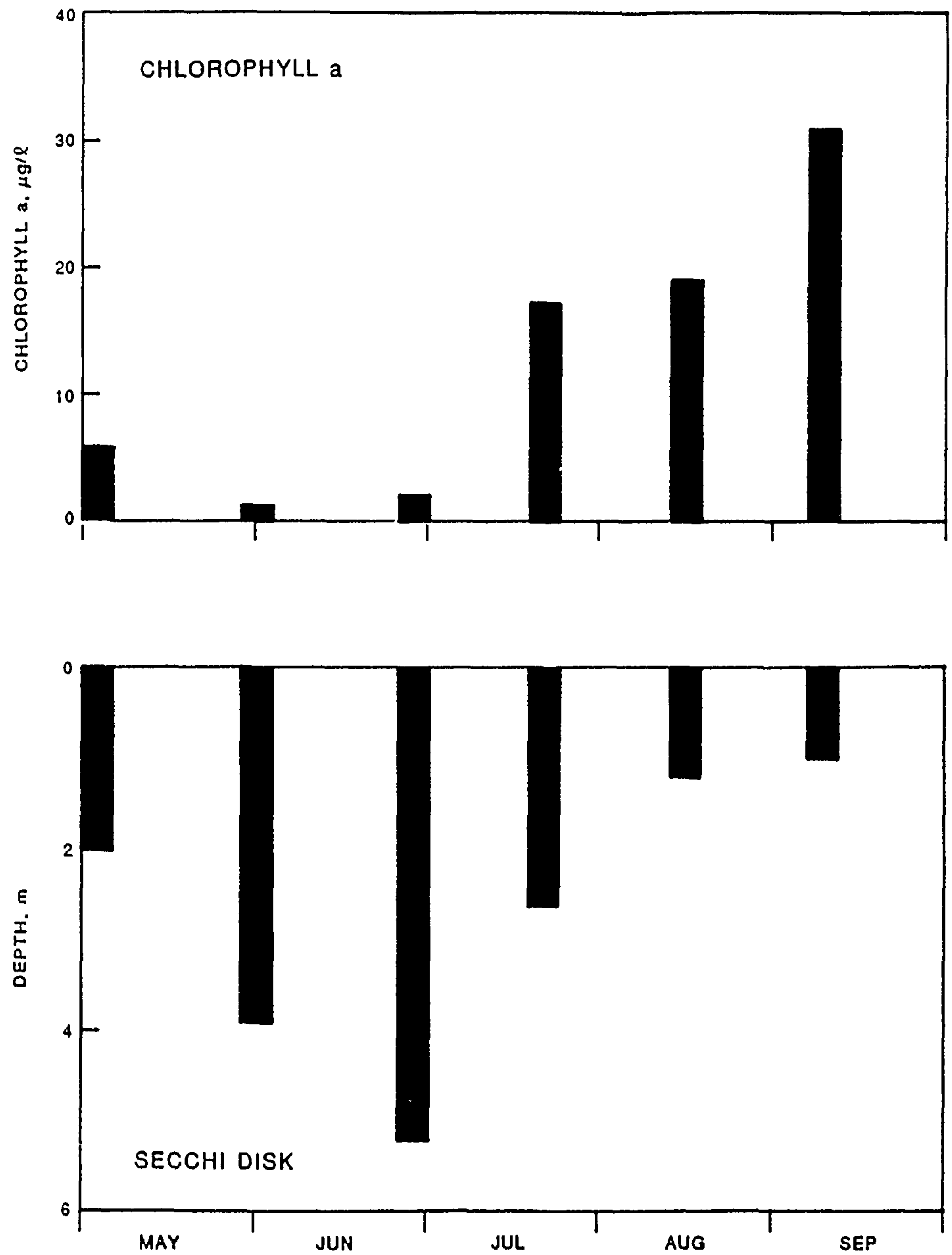


Figure 22. Temporal distribution of chlorophyll a concentrations (top) and Secchi disk depths (bottom) in East Sidney Lake, May-early September 1988

limitation, while ratios greater than 17 indicated phosphorus limitation. Furthermore, changes in species composition of the phytoplankton community may be effected due to changes in the limiting nutrient. For example, dominance by blue-green phytoplankton species capable of nitrogen fixing may be favored under conditions of nitrogen limitation.

The atomic ratio of total nitrogen-to-total phosphorus in the surface waters of Whitney Point Lake ranged from 6.2 to 19.2. Values were near 18 to 20 in May and early June and decreased to less than 10 for the remainder of the study period. At East Sidney Lake the atomic ratio of total nitrogen to total phosphorus in the surface waters ranged from 10.7 to 28.3 with values greater than 17 occurring in early May and late June. Ratios were between 10.7 and 12.4 mid July through September. As phosphorus concentrations increased, the potential for nitrogen limitation also increased, as indicated in decreased nitrogen to phosphorus ratios during the latter portion of the study period.

Changes in phytoplankton community structure throughout the growing season were apparent (Tables 8 and 9). While diatom species dominated at Whitney Point Lake in May and early June, a mixed community composed of diatoms, dinoflagellates and blue-greens existed in late June. After the return to stratification in July, diatoms were no longer a dominant species and green and blue-green species dominated the population. After autumnal turnover chlorophyll _a_ concentrations were at maximum observed levels and blue-green species dominated the population.

The phytoplankton community at East Sidney Lake was dominated by flagellates in early May and June (Table 9). Few diatoms were observed in these months. In July, blue-green species dominated the phytoplankton community and continued to dominate community structure for the remainder of the study period. Maximum chlorophyll _a_ concentrations were observed in September when a single blue-green alga, _Anabaena planktonica_, dominated the population.

Two distinct patterns in phytoplankton dynamics were clear based on assessments of chlorophyll _a_ concentrations and phytoplankton identification. First, increased chlorophyll _a_ concentrations coincided with increased total phosphorus concentrations observed in August and September, suggesting internal loading of phosphorus markedly impacted phytoplankton production. Secondly, the shift of total nitrogen to total phosphorus ratios to below 10 in late June suggests that nitrogen became the limiting nutrient in mid to

late summer and nutrient conditions favored blue-green phytoplankton species capable of nitrogen fixation.

Water Clarity

Decreased water clarity coincided with increased chlorophyll a concentrations (Figures 21 and 22). Secchi disk depths, which ranged from 0.6 to 1.6 meters in Whitney Point Lake, were mostly greater than one meter from May through July but decreased to less than one meter during August and September. Secchi disk depths were more variable in East Sidney Lake and ranged from 1.0 to 5.2 meters. Secchi disk depth exceeded 2 meters during early and mid summer with a maximum depth of 5.2 meters observed in late June.

Secchi disk depth provides an estimate of transparency in surface waters but does not distinguish factors which contribute to decreased water clarity. These factors are typically biological (e.g. phytoplankton) or nonbiological (e.g. suspended sediment) and distinction between the two is often useful in data interpretation for eutrophic systems. Walker (1987), following an assessment of a CE-wide database, suggests that nonalgal turbidity values less than 0.4 1/m reflect low turbidity systems while values greater than 1.0 1/m indicate high turbidity. An estimate of nonalgal turbidity was obtained for Whitney Point and East Sidney Lakes utilizing the following equation (Walker 1985):

$$a = 1/S - 0.025B$$

where:

a = nonalgal turbidity (1/m)
S = mean Secchi disk depth (m)
B = mean chlorophyll a concentration (mg/cu m)

Nonalgal turbidity values ranged between 0.41 and 0.76 at Whitney Point Lake, indicating intermediate turbidity, while at East Sidney Lake, nonalgal turbidity ranged from near 0.0 to 0.36. The near 0.0 value occurred in July when Secchi disk depth was 2.6 meters and chlorophyll a concentration was 17.2 μg/l. Maximum nonalgal turbidity values were observed in August and September, when water clarity was at a minimum. These data suggest that the light regime at both lakes is dominated by algal concentration.

Discharge Water Quality

Chemical conditions observed in the discharge from Whitney Point and East Sidney Dams reflected temporal trends observed at the in-lake stations (Figures 23 and 24). In general, concentrations were highest during discharge from snowmelt runoff and during the peak of thermal stratification. Following the period of snowmelt discharge, concentrations decreased until mid-summer. Discharge concentrations again increased as gradients in dissolved oxygen concentrations developed in the lake, with peak concentrations occurring in August. Concentrations decreased in the discharge following the fall mixing event. Although discharge concentrations were highest in late summer, discharge loads were highest during the spring high flow periods (Figures 25 and 26).

While effects on downstream water quality were not studied, elevated levels of nutrients and metals, in conjunction with low flow, may impact aquatic processes such as biological productivity and materials transport in the downstream area. Increased availability of nutrients may stimulate increased phytoplankton productivity which would impact spatial and temporal distribution of dissolved oxygen concentrations and increase organic loading downstream. Oxidation of reduced metals would impact dissolved oxygen concentrations and increase material loads due to the formation of particulates. Clearly, additional research is needed for increased understanding of aquatic processes in reservoir releases and delineating impacts on downstream water quality.

Summary of Water Quality Conditions

Low thermal stability of each lake during the summer growing season allows for intermittent stratification and destratification which may enhance the cycling of nutrients between sediments and surface waters. These conditions were more pronounced at Whitney Point Lake.

While inflow concentrations of total phosphorus were relatively constant during the summer growing season, significant ($p < .05$) increases in surface water concentrations of total phosphorus were observed. Surface water concentrations increased at rates of 0.3 and 0.2 μg-P/l per day for Whitney Point and East Sidney Lakes, respectively, suggesting pronounced internal loading of phosphorus.

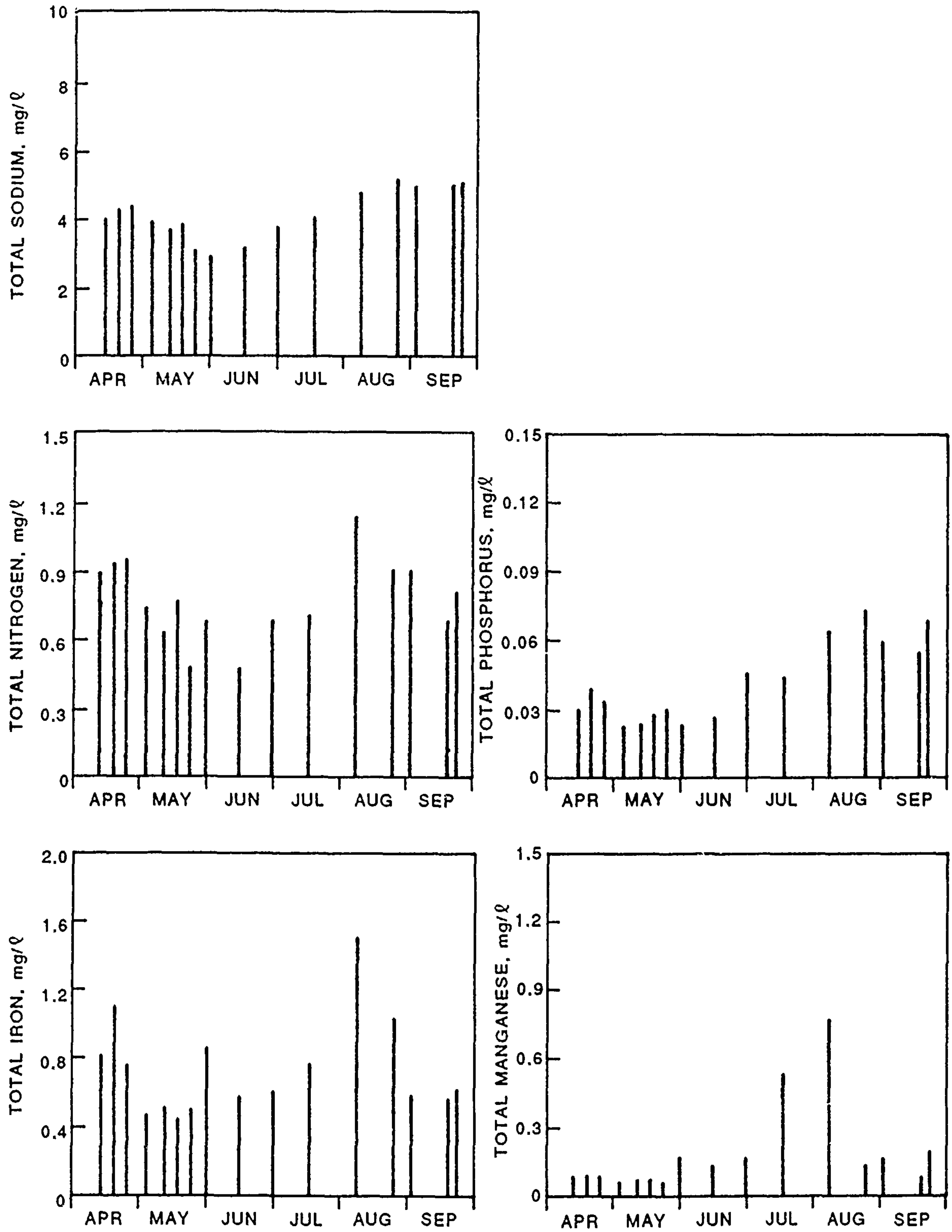


Figure 23. Discharge concentrations of nutrients and metals, Whitney Point Lake, April-September 1988

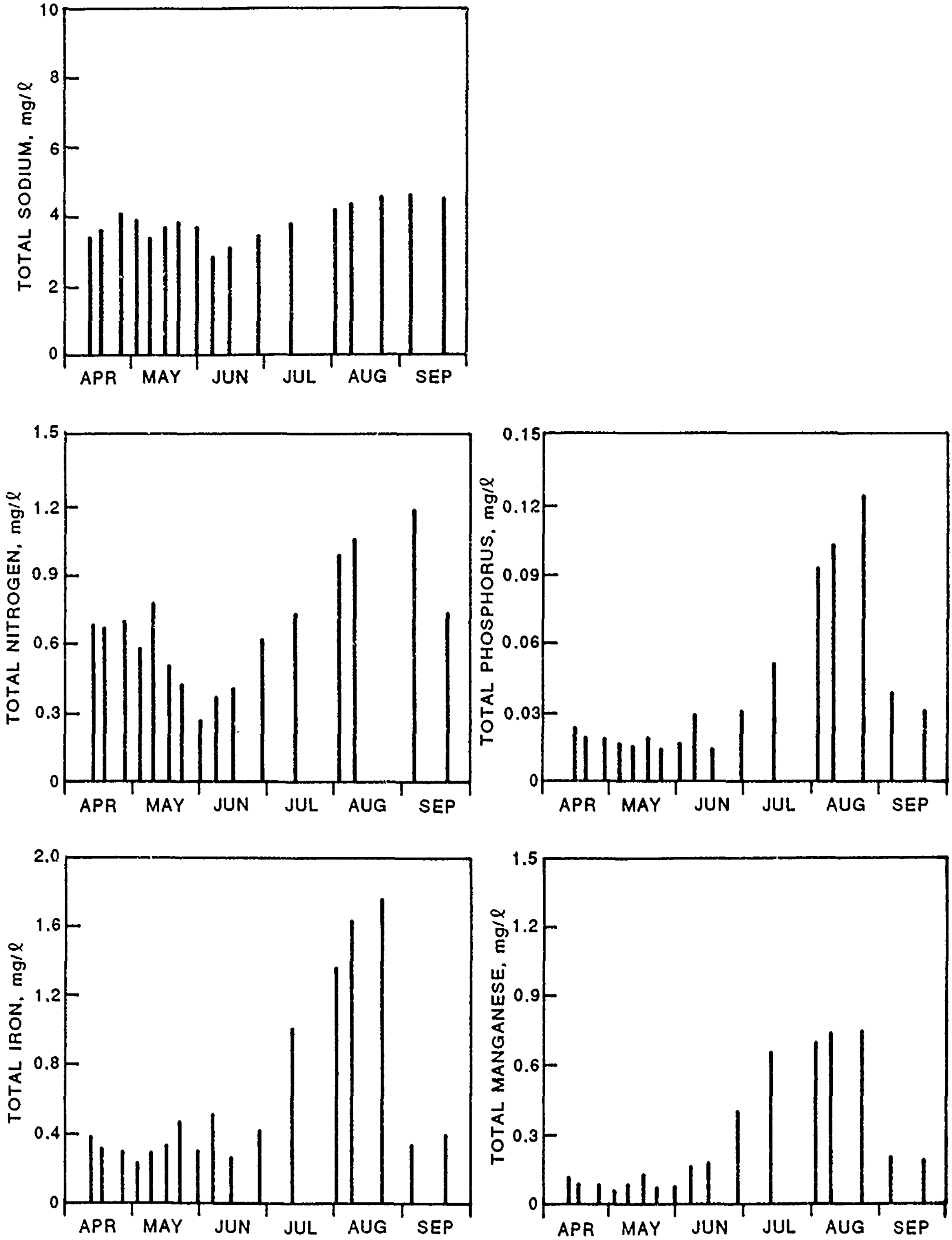


Figure 24. Discharge concentrations of nutrients and metals, East Sidney Lake, April-September 1988

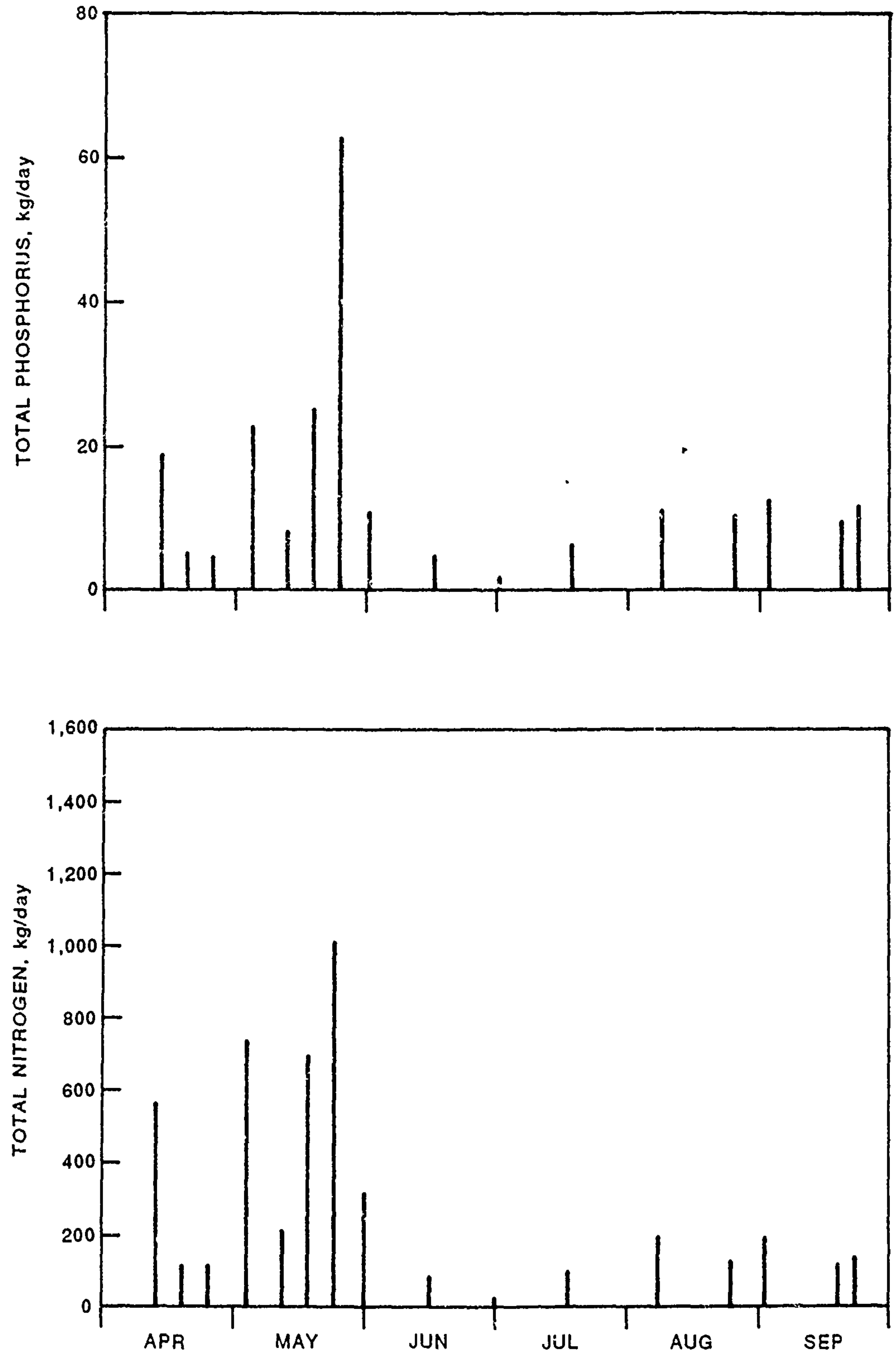


Figure 25. Instantaneous daily nutrient loads, discharge, Whitney Point Lake, April-September 1988

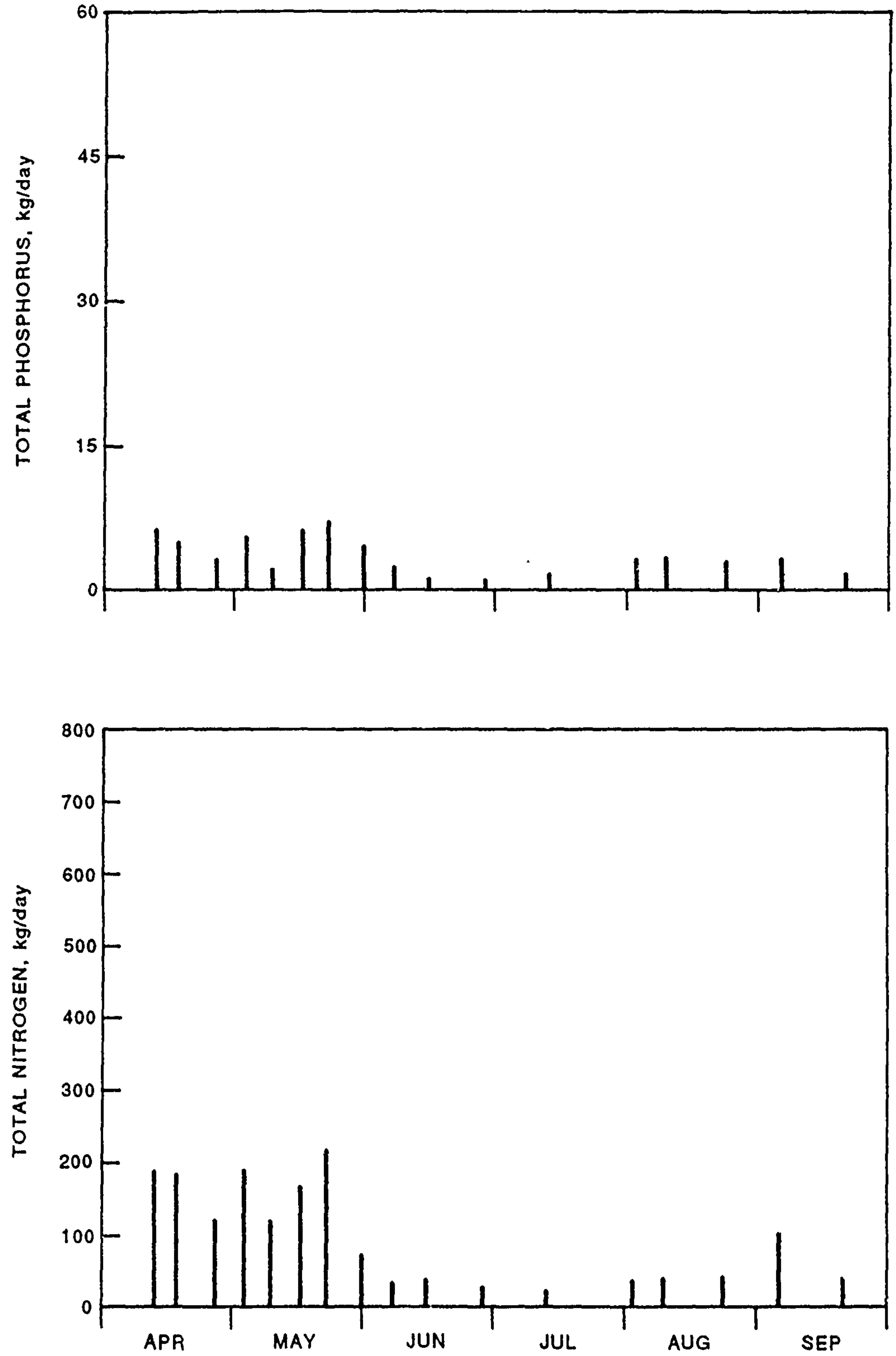


Figure 26. Instantaneous daily nutrient loads, discharge, East Sidney Lake, April-September 1988

Excessive concentrations of nutrients are a major factor in the proliferation of nuisance phytoplankton and the accompanying decline in water quality in reservoirs and lakes. Ambient concentrations in excess of 0.020 mg-P/l (Vollenweider 1968) to 0.030 mg-P/l (National Academy of Science 1972) are considered representative of eutrophic conditions in phosphorus-limited lakes. In-lake concentrations observed in surface waters during this study clearly fall within this range.

Phytoplankton responses to excessive nutrient concentrations were reflected in temporal trends in chlorophyll a concentrations. Concentrations of chlorophyll a between 5 to 140 μg/l are considered to be representative of eutrophic conditions in lakes not dominated by aquatic macrophytes (Sakamoto 1966). More specific values have been proposed for nonmacrophyte dominated lakes including greater than 10 μg/l (National Academy of Science 1972), greater than 8.8 μg/l (Dobson, Gilbertson, and Sly 1974), and greater than 12 μg/l (USEPA 1974). Clearly, observed chlorophyll a concentrations indicate eutrophic conditions, particularly in late summer.

Assessment of water quality conditions should also consider seasonal dominance of phytoplankton species. Early summer phytoplankton communities were dominated by "more desirable" species such as diatoms and green species. Blue-green species of phytoplankton, considered a nuisance in excessive concentrations, dominated the phytoplankton community during the latter portion of the growing season.

Also indicative of eutrophic conditions in late summer were decreases in water clarity. Secchi disk depths less than 2.0 m (USEPA 1974) and 3.0 m (Dobson, Gilbertson, and Sly 1974) are also considered to be representative of eutrophic systems. Observed Secchi disk depths fall well within these ranges, particularly during the latter portion of the growing season.

PART VI: USER PERCEPTIONS OF WATER QUALITY

In addition to flood control, Whitney Point and East Sidney Lakes provide recreational activities for project users. Perceptions of water quality are affected by the experience of a project user while engaged in activities at the lake. To determine user perceptions of water quality, a survey was conducted using questions about recreational activities at the lakes. Representative questions used in the survey are:

1. Who is using the project, when, and for what water recreation purposes?
2. Do the users perceive the existence of water quality problems?
3. What changes in water quality are desired?
4. Have recreation patterns, i.e. changes in activities, been affected by water quality?
5. Would improved water quality increase the quality of the recreation experience?
6. Do users understand the cause/effect relations associated with water quality?

Face-to-face interviews were conducted at each lake (52 at Whitney Point Lake and 48 at East Sidney Lake) between 1000 and 1830 hr on two weekday and two weekend days during the period 14-17 July. Interviews were conducted at beach, picnic area, boat ramp, boat rental area, and tailwater areas. Approximately 2-hr time blocks were used for surveying the areas. For camping areas, surveys were performed on weekend mornings (Saturday for East Sidney Lake and Sunday for Whitney Point Lake). Complete methods and detailed questionnaire analyses are included in Appendix D.

The majority of users live within 50 kilometers of the project and over half visit the projects more than 10 times during the summer. The 50-kilometer radius includes Broome, Otsego, Chenango, and Delaware counties and, for Whitney Point Lake, the Binghamton metropolitan area. The proximity of the lakes to residences is the most often cited reason for choosing the lake rather than some other lake. The projects are being used primarily for day use activities (i.e. beach, picnic), boating, and fishing.

Perceptions of water quality were assessed by asking users to assign ratings to existing water quality conditions, impacts on recreation activities, and the need for improvement in water quality. Water quality conditions did not interfere with or prevent recreation users from engaging in any of the activities that were planned, and respondents did not perceive a great need for improvement in water quality.

Responses to questions concerning improvements in water quality and the importance of various water quality parameters to users, reinforced responses to questions of perceptions of overall water quality. Twenty-six percent of the respondents said that water quality should be improved. The rankings assigned to these improvements were roughly in the order of water clearness, odor, debris, and "scum" in the water.

Water quality in the tailwater was considered separately. Approximately eighteen percent of the respondents use the tailwater. Roughly sixty-five percent said that water quality conditions in the tailwater are not different than conditions in the lake.

The level of user understanding of water quality was not readily discernible and may not have been adequately tested in the survey. Limited understanding of water quality was evident from explanations of fishing practices which revealed an understanding of temperature gradients and relationships of fish behavior.

Questions addressing the acceptability of water quality management suggested measures such as the use chemicals for algae and aquatic plant control, zoning and land use control, and enforcement of existing pollution laws. Respondents were highly supportive of existing control measures, but use of chemicals was clearly deemed unacceptable.

In summary, user perceptions of water quality are generally favorable. Recreational experiences are not impaired by water quality. Most users are local and may accept existing conditions as favorable due to limited understanding of water quality. However, nearly one-fourth of the users expressed a desire for water quality improvements and were supportive of institutional control measures. Desired water quality improvements may be associated with control of nuisance algal blooms.

PART VII: WATER QUALITY MANAGEMENT OBJECTIVES

Historically, principal water quality management objectives at Whitney Point and East Sidney Lakes have included maintaining acceptable water quality conditions, providing maximum beneficial low-flow releases, and meeting state water quality criteria for lakes and tailwaters (US Army Corps of Engineers 1983a and 1983b). Maximum beneficial low-flow conditions are provided on a water-availability basis and, thus are a function of hydrologic conditions. State water quality criteria, applicable at the projects, are maintenance of downstream temperature and dissolved oxygen values required for trout and other cold water fish species (New York State Department of Environmental Conservation 1986).

Additional management objectives at Whitney Point and East Sidney Lakes include reduction in phytoplankton growth and development and maintenance of fishery and recreational potential (US Army Corps of Engineers 1983a and 1983b).

In general, the principal water quality management objectives are met under routine operations at each project. As indicated from the user surveys, water quality is perceived as good and little need for improvement is suggested. However, detailed analysis of water quality throughout the summer growing season indicates potentially adverse water quality conditions such as anoxia, elevated concentrations of metals and nutrients, nuisance algal blooms, and reduced water clarity. Logically, management objectives should focus on minimizing the occurrence of these adverse conditions.

Reduction of late summer phytoplankton biomass is the primary objective for water quality enhancement at each project. Elevated biomass contributes to decreased water clarity and high organic loading to the hypolimnion. Furthermore, increased organic loading may increase oxygen depletion rates and internal loading of nutrients and metals. Consequently, fisheries are impacted by increased oxygen depletion, phytoplankton production increases due to increased nutrient loading, and downstream water quality is impacted by increased export of nutrients and metals. Clearly, reduction of phytoplankton biomass will lessen the severity of adverse impacts and provide water quality enhancement for existing management objectives.

Increased water clarity, particularly during the latter portion of the summer recreation season, would improve recreational experiences of project users. Decreased phytoplankton biomass, or a redistribution of the existing

population throughout a larger volume of water, would reduce the occurrence of nuisance algal blooms perceived by users as "scums."

Decreased materials cycling and the resultant decrease in oxygen depletion would likely have positive impacts on secondary productivity, such as fisheries. Increased habitat may result from expanded oxygenated regions. Food resources, such as zooplankton populations, may increase with improved water quality, thereby enhancing existing fisheries.

Decreased primary productivity, via reductions in nutrient availability, may also impact fisheries. Reductions in undesirable phytoplankton species may contribute to increases in desirable species and provide a positive impact on secondary productivity. Alternately, reductions in primary productivity may be considered as a negative impact on secondary productivity due to reductions in food resources.

Aquatic systems are often classified based on trophic indicators such as nutrient and chlorophyll concentrations and water clarity. Classification by trophic status allows comparison and ranking among aquatic systems and may assist in delineation of management needs. A trophic state index (TSI), using the above indicators, was developed by Carlson (1977) using the following equations.

$$TSI = 60 - 14.41(\ln \text{Secchi Disk})$$

$$TSI = 9.81(\ln \text{Chlorophyll } \underline{a} \text{ concentration}) + 30.6$$

$$TSI = 14.42(\ln \text{Total Phosphorus concentration}) + 4.15$$

Using this method of classification, both lakes may be classified as mesotrophic or eutrophic (Table 10).

More recently, classification of aquatic systems has been considered through assessment of user perceptions and related physicochemical water quality parameters. In developing phosphorus criteria for Minnesota lakes, Heiskary and Walker (1988), suggest establishing criteria based on the relationships of selected water quality indicators to locally perceived aesthetic quality. Critical phosphorus levels can then be established which correspond to adverse water quality. Management objectives would then be directed at maintaining phosphorus levels below the critical level. Limitations to this approach center around the feasibility of maintaining phosphorus levels below the critical level. An alternate approach is to define criteria

on a regional basis considering environmental factors which may predetermine minimum levels that can be attained. This approach has been proposed using ecoregions as the boundaries for establishing criteria (Hughes and Larsen 1988).

In general, values of trophic indicators for Whitney Point and East Sidney Lakes (this study) are within the range of values reported for other New York Lakes (Bloomfield 1978a)(Table 11). Total phosphorus and chlorophyll a concentrations (10-100 μg-P/l and 10-100 mg/l, respectively) have been reported for three eutrophic New York Lakes, Chautauqua, Onondaga, and Oneida Lakes (Bloomfield 1978b). While total phosphorus and chlorophyll a concentrations observed at Whitney Point and East Sidney were generally at or below the mid-point of these ranges, late summer phosphorus concentrations in the bottom waters at East Sidney Lake exceeded 100 μg-P/l. Similarities to other lakes in the same vicinity suggest although Whitney Point and East Sidney Lakes may be considered eutrophic, water quality is near "average" for the region.

Identification of water quality enhancement needs may be influenced by user perceptions, particularly since comparison of trophic indicators suggests "average" water quality. Water quality conditions at Whitney Point and East Sidney Lake at the time of the user survey, when water quality was perceived as good, must be interpolated from late June and July data. Pronounced changes in water quality during this period make interpolation difficult. Ambient total phosphorus concentrations were between 30-36 μg-P/l and 17-26 μg-P/l at Whitney Point and East Sidney Lakes, respectively.

Chlorophyll a concentrations were less than 10 μg/l at Whitney Point Lake and between 2 and 17 μg/l at East Sidney Lake. Secchi disk depths were between 1.0-1.6 m and 2.6-5.2 m at each lake, respectively. Shifts in phytoplankton community structure from "more desirable" phytoplankton species (diatoms and greens) to "less desirable" species (blue-greens) occurred during this period as well. Pronounced variability in water quality conditions precludes rigid establishment of management objectives from user perceptions alone.

Concepts from each of the aforementioned approaches may be applicable for establishing management goals at Whitney Point and East Sidney Lakes. Comparisons of selected water quality parameters between the two projects and nearby lakes provide a range of conditions for the region. Water quality conditions at the time of the user survey provide an estimate of "acceptable

limits" and "target levels" if reductions are required. Management goals can then be set to attain water quality values at the projects that are within an obtainable and acceptable range.

Specific water quality management goals at Whitney Point and East Sidney Lakes should focus on bringing values of summer chlorophyll a, total phosphorus, and Secchi disk depths closer to mean values observed for other New York lakes. While this goal is generally met during early summer, late summer values often exceed mean values of other area lakes. Hence, to obtain desired improvements in water quality, enhancement techniques should focus on factors contributing to adverse conditions observed in late summer. As discussed previously in this report, internal loading of phosphorus during anoxia stimulates phytoplankton production and results in increased chlorophyll a concentrations and decreased water clarity. Consequently, enhancement techniques which result in minimizing internal phosphorus loading and decreasing phytoplankton production should be employed to attain management goals.

Changes in water quality within the lake will be reflected in discharge water quality. Consequently, evaluation of enhancement techniques must consider impacts on discharge water quality.

PART VIII: SUMMARY AND RECOMMENDATIONS

Reductions in external nutrient loading, reductions in internal material cycling, and direct control of phytoplankton are three management techniques that may be used to control algal biomass at Whitney Point and East Sidney Lakes. Basic concepts of these approaches are presented in Table 12.

Reductions in nutrient loads can be approached in various ways. The most direct approach is focused at the primary source of the nutrients; the watershed. Opportunities for water quality enhancement due to reductions in external loading from the watershed include implementation of watershed management practices and application of treatments to inflows to the lakes. Watershed management is not specifically within the mission of the Corps of Engineers (CE), but recent emphasis from other agencies (Federal, state, and local) in improved water quality through watershed management provides opportunities for cooperative interactions (Nonpoint Source Task Force 1985).

Reduction in nutrient loads from internal sources can be accomplished using inlake techniques such as sealing of sediments for phosphorus inactivation, sediment removal, physical techniques such as mixing or aeration, and changes in operation such as pool fluctuations or changes in withdrawals.

Direct control of phytoplankton may be accomplished through manipulations of the community structure in an aquatic system. Changes in phytoplankton community structure may be affected through application of algicides and increased phytoplankton mortality by secondary producers. Additionally, physical mixing, resulting in redistribution, may promote changes in community structure due to different physiological characteristics of phytoplankton species.

Several management approaches were considered feasible and require further consideration. Project users supported institutional measurements for water quality enhancement such as watershed management for reduction of external nutrient loading. Limited potential for significantly increasing thermal stability at the lakes indicates that reductions in internal nutrient loadings and control of phytoplankton may be approached through maintenance of mixed conditions at the projects.

Specific recommendations for water quality enhancement are listed in the following.

1. Cooperative agreements should be established with state and local agencies to invoke best management plans, identify and reduce

seasonal land use practices which may adversely impact water quality, and provide for increased public awareness through educational programs at each project. Water quality enhancement opportunities at Whitney Point and East Sidney Lakes center around reductions in external and internal nutrient loading. Reductions in external nutrient loading are possible through watershed management programs.

2. Artificial circulation to prevent thermal stratification at the projects should be employed to reduce internal loading of nutrients. Mixing through artificial circulation prevents or disrupts thermal stratification dependent upon the timing and magnitude of implementation. Positive effects on water quality include increased aeration and chemical oxidation (thereby reducing internal nutrient cycling), enlarged habitat for aerobic organisms, and changes in phytoplankton biomass. Additionally, physical redistribution of phytoplankton may lessen the "apparent" severity of excessive phytoplankton biomass. Evaluation of artificial circulation at East Sidney Lake is presented in Appendix F.

3. A comprehensive monitoring program should be implemented in conjunction with water quality management approaches to evaluate the effectiveness on water quality enhancement.

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Table 1

Project Physical Characteristics *

Characteristic	Whitney Point Lake	East Sidney Lake
Volume (million cubic meters)	15.4	4.1
Maximum Depth (meters)	7.0	15.7
Mean Depth (meters)	3.2	4.9
Average Inflow Rate (cubic meters per second)	13.0	4.9
Hydraulic Residence Time (days)	13.5	9.8
Pool Surface Elevation (meters, NGVD)	296.5	350.5
Drainage Area at Dam (square kilometers)	660.0	264.0
Surface Area (hectares)	485.6	85.0
Drainage Area/Surface Area	136.0	311.0

* Denotes values for summer pool elevations

Table 2

Animal Activities in the Watershed of East Sidney Lake

Land use	Number of sites
Non-dairy operations (unconfined)	79
Dairy operations (unconfined)	52
Horse operations (unconfined)	2
Poultry operations (confined)	1
Swine operations (confined)	1

Table 3

Inflow Concentrations *

	Total Phosphorus	Total Nitrogen	Total Iron	Total Manganese	Total Sodium
Whitney Point Lake					
Otselic River					
Minimum	0.012	0.420	0.13	0.03	2.94
Maximum	0.032	0.980	0.67	0.08	6.15
Mean	0.022	0.743	0.39	0.05	5.00
CV	27.0	21.2	43.6	26.5	19.0
East Sidney Lake					
Ouleout Creek					
Minimum	0.010	0.330	0.07	0.02	3.03
Maximum	0.051	1.180	0.61	0.05	5.90
Mean	0.021	0.756	0.18	0.04	4.85
CV	54.8	33.8	92.9	33.6	16.7
Handsome Creek					
Minimum	0.010	0.170	0.04	0.01	1.98
Maximum	0.027	0.710	0.21	0.05	7.05
Mean	0.016	0.385	0.09	0.03	3.50
CV	39.2	35.9	51.7	53.7	44.8
PROB > |T|	0.1207	0.0001	0.0451	0.2205	0.0034

* Concentrations in mg/l

Table 4

Annual Loading Estimates for Total Phosphorus and Nitrogen at Whitney Point and East Sidney Lakes

	Total Phosphorus *	Total Nitrogen *
Whitney Point Lake		
87-88	6672	202046
Method 1 +	23628	477840
Method 2 +	31713	317658
East Sidney Lake		
87-88	3509	72329
Method 1 +	9451	191136
Method 2 +	12685	127063

* Rates in kg/yr
+ Method 1 provides values based on median export coefficients for 43 streams sampled by the National Eutrophication Survey.
Method 2 computes loads based on data obtained from the gauge located at Lamb's Creek on the Tioga River. Source, Kennedy et al., 1988

Table 5

Thermal Stability at Whitney Point and East Sidney Lakes *

Date	Whitney Point Lake	East Sidney Lake
5-5-88	7.0	12.5
6-1-88	9.2	4.7
6-30-88	not stratified	35.7
7-21-88	2.6	57.7
8-16-88	0.3	39.7
9-9-88	1.7	16.1

* Values expressed as gm-cm/sq cm

Table 6

Loading Estimates for Total Phosphorus, Nitrogen, and Sodium During the Summer Growing Season (June through mid-August)

	Total Phosphorus	Total Nitrogen	Total Sodium
Whitney Point Lake			
External load (kg)	400.8	11243.4	87022.6
Discharge loss (kg)	616.8	11553.2	66221.4
Change in storage (kg)	394.8	1276.8	30069.0
Net internal load (kg)	610.7	1586.6	9267.8
Total load (kg)	1011.5	12830.0	96290.4
East Sidney Lake			
Ouleout Creek load (kg)	60.6	2608.9	17101.8
Handsome Creek load (kg)	19.9	462.2	4203.5
Total external load (kg)	80.5	3071.1	21305.3
Discharge loss (kg)	210.4	3132.5	14892.6
Change in storage (kg)	59.5	726.2	6458.4
Net internal load (kg)	189.4	787.6	45.7
Total load (kg)	269.9	3858.7	21351.0

Table 7

Loading Rates for Total Phosphorus, Nitrogen, and Sodium During the Summer Growing Season (June through mid-August)

	Total Phosphorus	Total Nitrogen	Total Sodium
Whitney Point Lake			
External Loading Rate (mg/sq m/day)	0.96	26.92	208.4
Internal Loading Rate (mg/sq m/day)	1.46	3.80	22.2
Total Loading Rate (mg/sq m/day)	2.42	30.72	230.6
East Sidney Lake			
External Loading Rate (mg/sq m/day)	1.26	48.18	334.3
Internal Loading Rate (mg/sq m/day)	2.98	12.36	0.7
Total Loading Rate (mg/sq m/day)	4.24	60.54	335.0

Table 8

Dominant Phytoplankton Species - Whitney Point Lake

Date	Species
5-5-88	Melosira spp. Asterionella formosa
6-1-88	Asterionella formosa Rhizosolenia sp. Attheya sp.
6-30-88	Melosira spp. Cryptomonas spp. Ceratium hirundinella Anabaena planctonica
7-21-88	Aphanizomenon flos-aquae Anabaena sp. (colonial blue-greens)
8-16-88	Aphanizomenon flos-aquae Anabaena planctonica Coccoid sp. (colonial blue-greens) Coelosphaerium sp. Microcystis aeruginosa Gomphosphaeria sp.
9-9-88	Aphanizomenon flos-aquae Oscillatoria sp. Melosira spp.

Table 9

Dominant Phytoplankton Species - East Sidney Lake

Date	Species
5-4-88	*Cryptomonas* spp. *Peridinium* sp. or *Glenodinium* sp. *Mallomonas* spp. *Rhodomonas minuta* microflagellates
6-2-88	*Cryptomonas* spp. *Rhodomonas minuta* microflagellates
6-29-88	*Rhodomonas minuta* *Cryptomonas* spp.
7-22-88	*Aphanizomenon flos-aquae* *Anabaena planctonica* *Coelastrum reticulatum* var. *polychordon*
8-16-88	*Anabaena planctonica*
9-9-88	*Aphanizomenon flos-aquae* *Anabaena planctonica*

Table 10

Trophic Classification (after Carlson Trophic State Index (TSI), 1977)

	OLIGOTROPHIC		MESOTROPHIC		EUTROPHIC	HYPEREUTROPHIC
TSI	20	30	40	50	60	70
Whitney Point Lake						
Total Phosphorus			44 ------------- 61			
Secchi Depth				54 ---------- 68		
Chlorophyll a			47 ---------------- 67			
East Sidney Lake						
Total Phosphorus			44 -------- 56			
Secchi Depth		36 -------------------- 60				
Chlorophyll a		34 ---------------------------- 65				

Table 11

Values of Trophic Indicators of Selected New York Lakes, Whitney Point, and East Sidney Lakes

Lake	Average Summer Secchi Disk Depth (meters)	Average Summer Chlorophyll *a* (mg/cu m)	Average Winter Total Phosphorus (mg/cu m)
Conesus	4.9	6.3	17.6
Hemlock	3.5	6.4	10.9
Canadice	5.2	4.4	9.2
Honeoye	3.0	13.2	16.2
Canandaigua	4.1	2.6	10.1
Keuka	7.0	3.3	11.5
Seneca	3.6	7.1	17.8
Cayuga	2.1	8.7	21.1
Owasco	3.0	5.6	14.7
Skaneatel	7.0	1.4	7.7
Otisco	5.7	2.2	8.4
Mean	4.5	5.6	13.2
Whitney Point	1.2	16.0	17.8*
East Sidney	2.6	12.6	14.1*

* Denotes mean value in early May.

Table 12

Basic Concepts for Control of Algal Populations

Reduce Excessive External Nutrient Loads
I. Reduce Nutrient Export from Land Surfaces: (a) Institute best management practices through cooperative efforts with state and local agencies. (b) Encourage conservation and pollution abatement efforts through public education and technical support. II. Intercept Loads: (a) Construct catchment basins or wetlands along major drainages within the watershed. (b) Construct nutrient and sediment detention basins along major tributaries.
Reduce Internal Material Cycling
I. Sediment Removal: (a) Remove all recent sediments from areas located below the normal elevation of the summer thermocline. (b) Remove those sediments most active in the release of materials to the overlying water column. II. Modify Sediment/water Interactions: (a) Install physical barriers over sediments. (b) Treat hypolimnetic sediments with aluminum or ferric salts. (c) Treat hypolimnetic sediments with an oxidant. (d) Modify water column characteristics. III. Modify Material Exchanges in the Water Column: (a) Modify outlet design and operation to increase thermal resistance to mixing. (b) Destratify to improve mixing and reaeration characteristics.
Direct Control of Phytoplankton
I. Increase Mortality: (a) Apply algicides during periods of excessive growth. (b) Increase grazing by zooplankton by manipulating the structure of the fish community. II. Modify Physical and Chemical Characteristics of the Water Column: (a) Reduce nutrient availability during critical periods of the year. (b) Increase the depth of the mixed layer relative to the photic zone.

APPENDIX A: MATERIALS AND METHODS

Assessment of Aerial Photographs

Aerial photography of the Whitney Point and East Sidney Lakes' watersheds was conducted in April, 1988, prior to development of spring foliage. Stereoscopic infrared color film was exposed along straight and level flight lines at an altitude of 3657.6 m above the ground surface. The photographs overlap by at least 50%. Images are at a scale of 1:24,000 which coincides with topographic quadrangles and high altitude aerial photographs. Overlapped photographs are viewed through a stereoscope which provides a three-dimensional image of the ground that highlights subtle topographic features, such as slopes and micro-drainages patterns (Perchalski and Higgins 1988). Infrared color film produces false color of vegetation which helps in delineation of forestry and agricultural features of the watershed.

Assessment of photographs from the East Sidney Lake watershed was conducted by personnel of the Mapping Services Branch of the Tennessee Valley Authority (TVA). Land use patterns such as forested areas, cropland, pastures, and urban development were delineated. Water sources and drainages were identified. Soil characteristics and runoff patterns were assessed to determine potential for animal waste runoff. A complete inventory of sites of animal activity, classified by animal type, degree of confinement, and proximity to drainage pathways, was conducted. Data were used to produce acetate maps of identified watershed features which overlay aerial photographs and topographic quadrangles at the same scale forming an atlas of the project watershed. Data are also tabulated and available on computer diskette.

Water Quality Sampling Methods

Data collection was conducted at inflow, in-lake, and outflow stations at each lake (Figures A1 and A2). Sample design was based on recommendations from a previous study (Kennedy et al. 1988). Sampling period was initiated in early April, 1988 and completed in early September, 1988. In situ variables, measured at in-lake stations, included water temperature, dissolved oxygen concentration, and specific conductance. Water samples for chemical analyses were collected at inflow, in-lake, and outflow stations. Chemical analyses included total sodium, nitrogen, phosphorus, iron, and manganese.

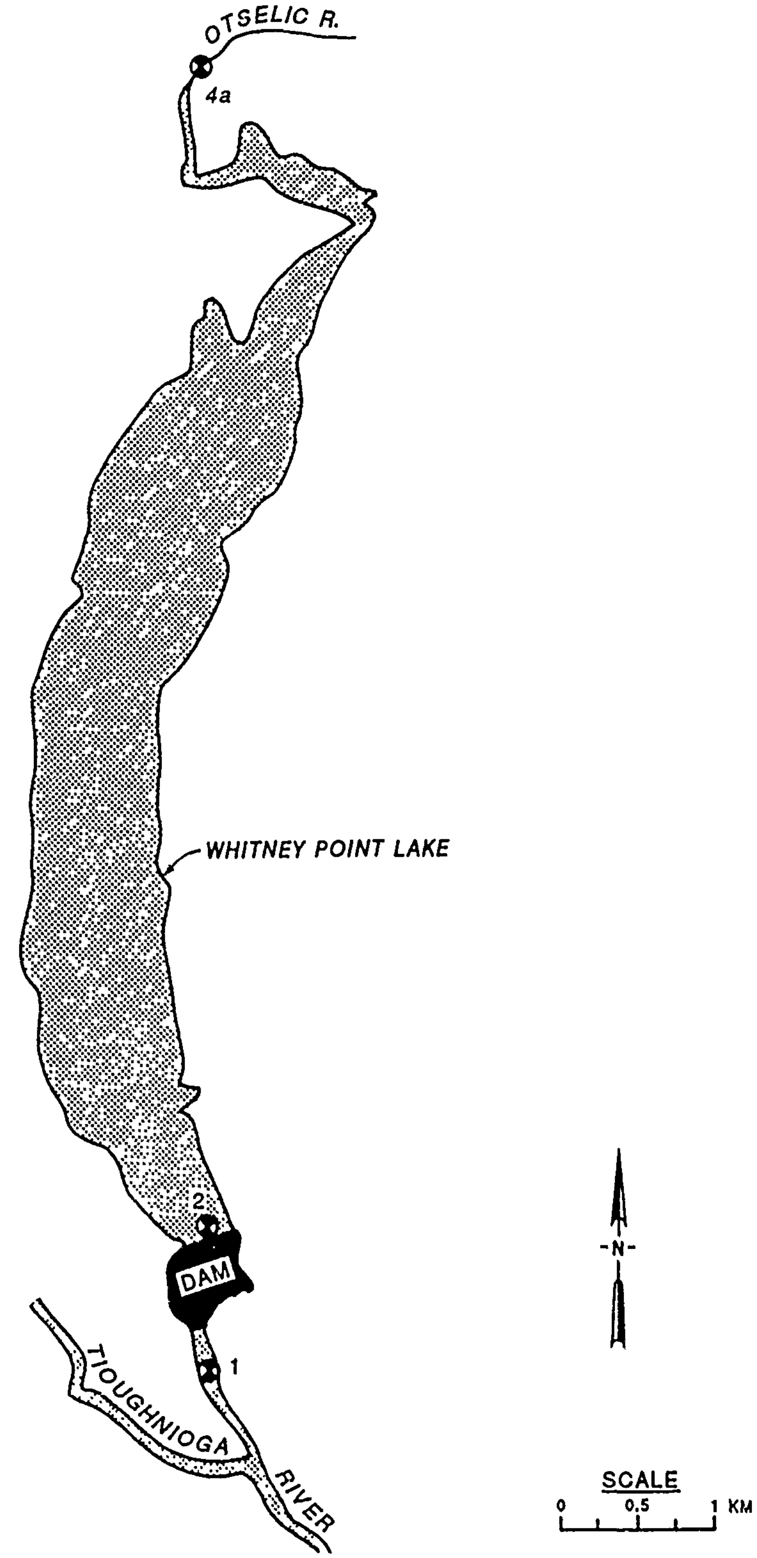

Figure A1. Station location map, Whitney Point Lake

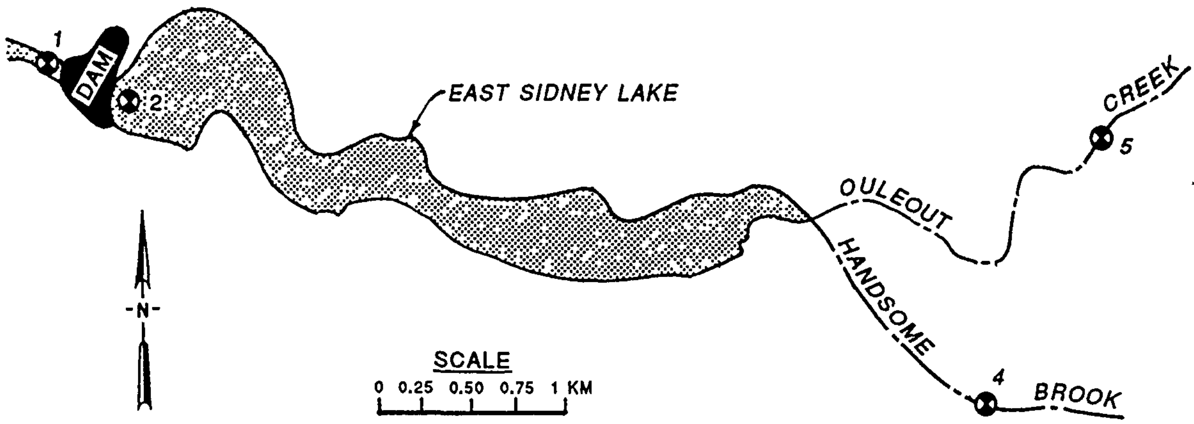

Figure A2. Station location map, East Sidney Lake

Inflow and outflow stations were sampled weekly during high-flow periods in spring and fall and biweekly during low-flow periods. Water samples for chemical analyses were collected with a clean bucket by NAB project personnel at each station. Samples were collected as close to mid-stream as possible with minimum disturbance to the stream bed. The bucket was filled in flowing water and the sample was considered to be representative of water quality at the station at the time of sampling.

The in-lake station on each lake was sampled six times between early May and early September. In-lake data collection included profiles at one-meter intervals at each station for temperature, dissolved oxygen, and specific conductance. Water samples for chemical analyses were collected with a Van Dorn sampler at surface, mid, and bottom depths (between one meter and one half meter from bottom). Secchi disk measurements (depth of disappearance and reappearance of the disk) were conducted to describe water clarity. Samples for chlorophyll analysis and phytoplankton identification were collected as integrated samples obtained from the water column to a depth of twice the Secchi disk depth or to a 3 meter maximum depth. Integrated samples were collected with a clean 3.8 cm (inside diameter) polyvinylchloride pipe fitted with a one-way check valve. The sampler was lowered to the desired depth at a rate which filled the sampler as it was lowered.

Analytical Methods

In situ determinations were conducted with a dissolved oxygen meter and a specific conductance meter with a thermistor (Model 57 and 33, respectively, Yellow Springs Instrument Co., Yellow Springs, OH). Total iron, manganese,

and sodium samples were digested with a nitric acid reflux procedure (American Public Health Association (APHA) 1980) and analyzed with an atomic adsorption spectrophotometer employing an air/acetylene flame (Model 4000, Bodenseewerk Perkin-Elmer and Company, Uberlingen, West Germany). Samples for total phosphorus and nitrogen were subjected to a persulfate oxidation digestion prior to analysis (APHA 1980).

Determination of total phosphorus employed automated colorimetric analysis using the ascorbic acid reduction method at 880 nm (APHA 1980). Total nitrogen analysis was conducted on an aliquot of the digested sample following a 24-hour reduction to ammonium with DeVarda's alloy (50% Cu, 45% Al, 5% Zn) (Raveh and Avnimelech 1979). Automated colorimetric analysis employed the phenate method at 630 nnm (APHA 1980). Automated colorimetric determinations were conducted with a Technicon AAII system (Technicon Industrial Systems, Tarrytown, NY). Samples for chlorophyll analysis were filtered within four hours of collection and the filters were frozen until analysis. Chlorophyll determinations were conducted using a dimethylformamide extraction procedure (Hains 1985) and spectrophotometric determination. Phytoplankton identification was conducted on an inverted microscope.

In situ and chemistry data from this study are included as Appendix B. A complete list of observed phytoplankton species is included as Appendix C.

APPENDIX B - WATER QUALITY DATA - 1988
WHITNEY POINT AND EAST SIDNEY LAKES, NEW YORK

Table B-1: WHITNEY POINT LAKE

DATE	STA	DEPTH	DO	TEMP	SP COND	TFe	TMn	TP	TN	TNa	CHLA	SECCHI
05MAY88	2	0.0	9.3	13.5	.						5.89	1.4
		1.0	9.4	13.3	.	0.32	0.05	0.017	0.65	4.75		
		2.0	9.8	11.5	.							
		3.0	9.2	9.7	.							
		4.0	10.0	9.5	.	0.41	0.05	0.019	0.73	3.96		
		5.0	9.9	9.4	.							
		6.0	9.8	9.2	.							
		7.0	9.0	9.1	.	0.87	0.12	0.033	0.82	3.75		
		8.0	7.9	9.0	.							
01JUN88	2	0.0	10.2	21.6	100						5.71	1.4
		1.0	10.1	21.4	105	0.27	0.03	0.016	0.68	2.87		
		2.0	10.4	21.3	105							
		3.0	10.4	21.3	130							
		4.0	9.8	19.4	125							
		5.0	7.3	16.0	120	0.64	0.10	0.024	0.69	2.66		
		6.0	6.5	15.4	115							
		7.0	7.0	14.9	115	0.92	0.15	0.035	0.78	2.70		
		8.0	4.0	14.7	115							
30JUN88	2	0.0	7.2	20.4	150						9.73	1.0
		1.0	7.3	21.0	160	0.40	0.11	0.037	0.71	4.15		
		2.0	7.3	21.0	160							
		3.0	7.4	21.0	165							
		4.0	7.1	21.1	165	0.39	0.11	0.034	0.67	4.00		
		5.0	6.9	21.0	165							
		6.0	6.8	21.2	165							
		7.0	6.8	21.1	170	0.53	0.13	0.021	0.76	3.95		

Table B-1: (continued)

DATE	STA	DEPTH	DO	TEMP	SP COND	TFe	TMn	TP	TN	TNa	CHLA	SECCHI
21JUL88	2	0.0	8.1	25.0	140						8.61	1.6
		1.0	8.1	25.0	145	0.12	0.07	0.029	0.62	4.70		
		2.0	7.6	24.6	145							
		3.0	6.3	23.4	150							
		4.0	3.0	24.0	145	0.18	0.19	0.032	0.77	4.35		
		5.0	1.0	20.8	150							
		6.0	0.5	20.0	150	1.87	1.02	0.060	1.11	4.35		
		7.0	0.2	19.3	175							
		8.0	0.1	17.8	180							
16AUG88	2	0.0	10.1	26.6	150						26.82	0.9
		1.0	10.1	26.7	150	0.24	0.06	0.043	0.77	4.80		
		2.0	10.0	26.7	155							
		3.0	10.0	26.5	160							
		4.0	9.9	26.5	160	0.27	0.06	0.042	0.74	4.80		
		5.0	9.8	26.4	160							
		6.0	9.6	26.0	160	0.31	0.06	0.045	0.77	4.65		
		7.0	8.3	25.8	160							
09SEP88	2	0.0	14.0	18.9	135						39.50	0.6
		1.0	14.3	18.9	130	0.38	0.07	0.050	0.68	4.90		
		2.0	12.3	19.3	135							
		3.0	10.6	19.2	135							
		4.0	9.1	18.5	135							
		5.0	8.4	18.3	135	0.43	0.07	0.052	0.73	4.75		
		6.0	7.6	17.4	140							
		7.0	7.2	17.4	140							
		8.0	7.9	17.2	140	0.76	0.12	0.070	0.81	4.90		

Table B-2: EAST SIDNEY LAKE

DATE	STA	DEPTH	DO	TEMP	SP COND	TFe	TMn	TP	TN	TNa	CHLA	SECCHI
04MAY88	2	0.0	12.7	13.0	.						5.92	2.0
		1.0	12.0	9.9	.	0.15	0.05	0.015	0.69	3.64		
		2.0	12.1	9.1	.							
		3.0	11.4	9.0	.							
		4.0	10.0	8.7	.							
		5.0	8.4	8.4	.							
		6.0	7.9	7.9	.							
		7.0	7.5	7.2	.	0.12	0.05	0.011	0.70	3.13		
		8.0	6.9	7.1	.							
		9.0	6.6	7.0	.							
		10.0	6.3	6.9	.							
		11.0	6.2	6.8	.							
		12.0	6.0	6.8	.	0.39	0.07	0.018	0.71	3.15		
		13.0	6.0	6.9	.							
02JUN88	2	0.0	9.0	9.9	90						1.12	3.9
		1.0	8.8	9.7	95	0.09	0.03	0.017	0.52	2.76		
		2.0	9.0	9.6	90							
		3.0	8.9	9.5	90							
		4.0	8.9	9.5	95							
		5.0	8.9	9.0	95							
		6.0	8.8	8.6	90							
		7.0	8.8	8.4	90	0.16	0.04	0.016	0.56	2.96		
		8.0	8.8	8.3	90							
		9.0	8.5	8.3	90							
		10.0	8.3	8.0	90							
		11.0	8.1	8.0	90							
		12.0	7.9	7.8	90							
		13.0	5.3	7.5	100	1.28	0.34	0.043	0.74	2.77		

Table B-2: (continued)

DATE	STA	DEPTH	DO	TEMP	SP COND	TFe	TMn	TP	TN	TNa	CHLA	SECCHI
29JUN88	2	0.0	7.7	21.4	80						2.00	5.2
		1.0	7.8	21.5	80	0.06	0.02	0.016	1.00	3.85		
		2.0	7.9	21.0	90							
		3.0	7.9	20.9	90							
		4.0	7.8	20.8	90							
		5.0	7.9	20.2	90							
		6.0	6.4	18.3	85	0.13	0.04	0.012	0.62	3.45		
		7.0	6.1	17.7	80							
		8.0	5.3	17.0	85							
		9.0	5.3	16.4	90							
		10.0	2.3	16.0	90							
		11.0	1.6	15.7	95	2.15	1.28	0.085	1.24	3.40		
		12.0	0.2	15.0	100							
		13.0	0.2	14.3	95							
22JUL88	2	0.0	9.8	24.7	90						17.15	2.6
		1.0	9.8	24.7	95	0.04	0.03	0.025	0.66	4.15		
		2.0	9.8	24.6	100							
		3.0	9.5	24.5	100							
		4.0	7.5	24.0	100							
		5.0	8.2	22.5	95	0.10	0.04	0.024	0.65	4.25		
		6.0	6.0	20.6	90							
		7.0	3.1	19.2	90							
		8.0	1.6	18.7	90							
		9.0	0.4	18.1	95							
		10.0	0.2	17.5	95	1.34	0.79	0.77	0.87	4.10		
		11.0	0.1	16.8	100							
		12.0	0.1	16.5	115							
		13.0	0.1	14.3	140							

Table B-2: (continued)

DATE	STA	DEPTH	DO	TEMP	SP COND	TFe	TMn	TP	TN	TNa	CHLA	SECCHI
16AUG88	2	0.0	8.1	26.1	100						18.88	1.2
		1.0	7.8	26.0	105	0.16	0.08	0.030	0.71	4.40		
		2.0	7.1	25.5	105							
		3.0	7.8	25.5	105							
		4.0	0.6	24.8	105							
		5.0	0.2	24.0	105							
		6.0	0.2	22.6	100							
		7.0	0.2	22.0	100	0.19	0.16	0.021	0.61	4.30		
		8.0	0.2	21.1	100							
		9.0	0.1	20.5	105							
		10.0	0.2	19.7	110	2.33	0.91	0.169	1.61	4.35		
		11.0	0.2	19.1	115							
		12.0	0.2	16.8	115							
09SEP88	2	0.0	13.8	20.1	90						30.85	1.0
		1.0	14.1	18.5	90	0.17	0.04	0.035	0.96	4.40		
		2.0	12.2	18.2	90							
		3.0	9.0	18.0	90							
		4.0	8.1	17.9	90							
		5.0	7.6	17.8	90							
		6.0	8.8	17.7	90							
		7.0	9.7	17.4	100	0.22	0.13	0.029	0.77	4.50		
		8.0	10.0	17.3	100							
		9.0	10.2	17.0	100							
		10.0	9.8	16.9	100							
		11.0	9.5	16.5	100							
		12.0	8.6	16.2	100							
		13.0	7.6	16.0	100	0.25	0.15	0.030	0.71	4.55		

APPENDIX C: INVENTORY OF PHYTOPLANKTON

Table C-1

Whitney Point Lake

5-5-88	Melosira spp. Asterionella formosa Stuarastrum Synedra Dinobryon bavaricum Cryptomonas Ankistrodesmus Dinobryon sp. Schroederia Scenedesmus
6-1-88	Asterionella formosa Rhizosolenia Attheya Melosira Pediastrum tetras Cryptomonas Rhodomonas minuta Mallomonas Scenedesmus spp. Fragilaria crotonensis Coelastrum microporum Ankistrodesmus
6-30-88	Melosira Cryptomonas Ceratium hirundinella Aphanizomenon flos-aquae Asterionella formosa Ankistrodesmus Scenedesmus Fragilaria crotonensis Synedra Dictyosphaerium Anabaena planctonica Microcystis Anabaena (coiled) Coelosphaerium Coelastrum microporum Pediastrum Staurastrum
7-21-88	Aphanizomenon flos-aquae Staurastrum (3 spp.) Microcystis aeruginosa Anabaena spp. Coelosphaerium duplex v. reticulatum Coelastrum cambricum Ceratium hirundinella Cryptomonas Gomphosphaeria Pediastrum simplex v. duodenarium Dictyosphaerium Schroederia Eucapsis Selenastrum Cyclotella Ankistrodesmus Oscillatoria Scenedesmus spp. Crucigenia Trachelomonas Tetraedron
8-16-88	Aphanizomenon flos-aquae Anabaena planctonica Coccoid cells Coelosphaerium Microcystis aeruginosa Gomphosphaeria Pediastrum simplex v. duodenarium Oscillatoria Melosira spp. Anabaena Staurastrum spp. Cosmarium

Table C-1 (continued)

8-16-88	<u>Trachelomonas</u> <u>Cryptomonas</u> <u>Synedra</u> <u>Botryococcus</u> <u>Ankistrodesmus</u> <u>Chroococcus</u>	9-9-88	<u>Aphanizomenon</u> <u>flos-aquae</u> <u>Oscillatoria</u> <u>Melosira</u> spp. <u>Euglena</u> <u>Ketablepharis</u> <u>Cyclotella</u> <u>Cryptomonas</u> spp. <u>Ceratium</u> <u>hirundinella</u> <u>Coelosphaerium</u> <u>Anabaena</u> spp. <u>Microcystis</u> <u>Nitzschia</u> <u>Staurastrum</u> <u>Mallomonas</u> spp. <u>Trachelomonas</u> <u>Ankistrodesmus</u>

Table C-2

East Sidney Lake

5-4-88	Cryptomonas spp. Peridinium sp. or Glenodinium sp. Mallomonas spp. Synedra Ankistrodesmus Asterionella formosa Chlamydomonas Anabaena Rhodomonas minuta Ketablepharis Ophiocytium microflagellates	7-22-88	Aphanizomenon flos-aquae Anabaena planctonica Coelastrum reticulatum v. polychordon Coelosphaerium Oocystis Cryptomonas Chroococcus Cosmarium Microcystis aeruginosa Rhodomonas Schroederia
6-2-88	Cryptomonas Rhodomonas minuta Synedra Asterionella formosa Ketablepharis Schroederia setigera Cyclotella Botryococcus microflagellates	8-16-88	Anabaena planctonica Aphanizomenon flos-aquae Cryptomonas Coelosphaerium Gomphosphaeria
6-29-88	Rhodomonas Cryptomonas Ophiocytium Gloeocystis Sphaerocystis Oscillatoria Anabaena Crucigenia rectangularis Aphanizomenon flos-aquae Mallomonas Ceratium hirundinella Staurastrum Coelosphaerium Schroederia Quadrigula Oocystis Microcystis	9-9-88	Aphanizomenon flos-aquae Anabaena planctonica Cryptomonas spp. Coelastrum reticulatum v. polychordon Coelosphaerium Schroederia setigera Ceratium hirundinella Anabaena spp. Scenedesmus spp. Staurastrum Oocystis Microcystis aeruginosa

APPENDIX D: QUESTIONNAIRE ANALYSIS[1]

Contents

[1] This section was prepared by Mr. Jim E. Henderson, Resource Analysis Group, Environmental Laboratory, US Army Engineer Waterways Experiment Station.

Project Users

To determine major recreational uses at Whitney Point and East Sidney Lakes, questionnaire respondents were asked whether they participated in fishing, boating, and beach activities (Table 1). Beach activities were predominant at Whitney Point Lake followed by boating then fishing. At East Sidney Lake, boating was slightly higher than beach activities and fishing.

The question about seasonal use of the lake indicated that the summer users, i.e. respondents to this questionnaire, used the lakes very little during the other seasons (Table 2). Because of the differences in recreation activities, during the other seasons, differences in the recreation patterns and perceptions would be expected if the survey had been performed in the winter.

Of the respondents, 8.2% were first time visitors to the lakes overall with 9.2% for Whitney Point Lake and 6.7% for East Sidney Lake. In examining use patterns, a major question is "Where do recreationists come from?" For these projects, the summer use is basically local or regional in character (Table 3). Almost 90% of the respondents travel 30 miles or less to the lake. The percentage of Whitney Point Lake users that travel 21 to 30 miles indicates that the Binghamton metropolitan area provides nearly a third of the users for Whitney Point Lake. At East Sidney Lake, most of the recreation users came from the nearby towns and county area. Conversations with the East Sidney Lake respondents indicated that there appears to be a large summer population. That is, people from "the city" have second or summer homes nearby. Had this been anticipated, a "primary or secondary residence" question could have been added to the survey.

When asked why respondents chose this lake rather than another lake, they responded with one or two reasons. The most often mentioned reason was close proximity of the lake (Table 4)[2]. Other reasons mentioned for choosing the lake include good fishing, good area for children, and large lake. The proximity of the lakes to residences appears to be the reason for choosing to recreate there, rather than choosing the lake for specific characteristics, such as unique facilities or exceptional fishing.

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[2] Respondents gave one or two answers to this question. For multiple answers, respondents were not asked to prioritize the reasons.

Perceptions of Water Quality

Perceptions of water quality indicated that the quality is generally good. Ratings of overall water quality showed that 55 (60.5%) of the respondents rated overall water quality as either a 4 or 5 (5 is High Quality, 1 is Low Quality) (Table 5). A slightly higher number (26 or 63.4%) of respondents at East Sidney Lake rated quality as a 4 or 5, as at Whitney Point Lake (26 or 58%). These perceptions were reinforced by 67.7% agreeing or strongly agreeing with the statement "Water quality of the lake is just right" (Table 6). Visitor judgments that water quality is just right is shown by the 67.7% agreement, slightly lower for East Sidney Lake and slightly higher for Whitney Point Lake. In looking at improvement of water quality conditions, half of the respondents were undecided as to whether conditions have improved over the years (Table 7). At East Sidney Lake, the perception is about evenly divided between "Undecided" and agreeing that water quality is improving. While at Whitney Point Lake there were a greater number of people that are "Undecided," not agreeing that water quality is improving.

When asked about needed improvements in water quality, respondents indicated that water quality conditions should not be improved. The verbal comments to these questions indicated that "there are no problems or things are just fine." The response to Question 20 indicates that the water quality is not in need of improvement (Table 8). For Question 36 (Table 9), the percentages disagreeing with the statement are same for both lakes, with higher agreement for improvement at East Sidney Lake.

A major consideration in any operation action is how conditions affect use of the lake (Tables 10 to 12). Perceptions of existing water quality conditions indicate that conditions do not interfere with any activities and that enjoyment of the trip would not be increased even if water quality were improved. The high percentage of "Disagree" respondents indicates that water quality conditions did not interfere with recreation activities. The water quality conditions did not prevent respondents from participating in recreation activities. The percentage of respondents above that indicated water quality did not affect the activities should be viewed with responses to other questions (Tables 11, 12). Twice as many respondents indicated that an improvement in water quality would not affect their enjoyment of the trip. However, the number of Agree responses may also be interpreted as "the cleaner the water, the greater the enjoyment."

Overall 75.5% of respondents disagreed with the statement about boat operations (Question 10, Table 11); while 18.4% agreed with the statement. Examining the lakes separately, 6 respondents (27.3%) at Whitney Point Lake agreed with the "interfered with boat operation" statement. Five respondents (18.5%) at East Sidney Lake responded that the conditions may not prevent respondents from boating, however, conditions may still interfere with boat operation.

Several questions were asked to determine perceptions of the effect users of the lakes have on water quality. Perceptions are that fishing and swimming do not contribute to poor water quality (Table 13). When asked to Agree or Disagree with the statement "Boaters do not affect water quality," overall 41.1% Disagreed with the statement indicating that boat operations are perceived as affecting water quality (Table 14). There is a difference on this question between the two lakes. At Whitney Point Lake, 57.7% Agreed with the statement with 36.5% Disagreeing or Strongly Disagreeing. A different pattern is shown at East Sidney Lake where 62.8% Disagreed and only 20.9% Agreed.

Improvement of Water Quality Parameters

To determine the importance of water quality parameters, respondents were asked to rate different parameters as VERY IMPORTANT to NOT IMPORTANT using a 5 to 1 scale. Of the 26 respondents that said water quality should be improved, the only clear priority is that clearness of the water was the HIGHEST PRIORITY (Table 15). There were no significant differences between the two lakes.

The importance of the different water quality parameters is shown in Tables 16, 19, 20, 22, 25, 27, and 28. The results are organized by clearness of the water, odor, debris in the water, scum in the water, aquatic plants, water temperature, and lake water level.

Questions about importance of clearness of the water included clarity of water, color, and cloudiness.

Of the stated needs for improvement, odor came in as second priority and this is supported by the importance rating for "No obnoxious odors" (Table 19).

Perceptions of importance of lack of debris in the water were elicited by a rating of importance (Table 20) and a question about relation to boating (Table 21).

While scum in the water is perceived as an important water quality consideration (Table 22), it is not presently a nuisance, (Table 23), as is also the case with algae (Table 24).

The absence of aquatic plants is important (Table 25), but not presently perceived as in need of improvement.

Presently, water temperature is seen as being about right (Table 26) and warm water is perceived as highly important (Table 27).

Respondents indicated that a high water level is important (Table 28).

Fishing Questions

Of the 98 respondents, 32 fished during the summer (12 from Whitney Point Lake and 20 from East Sidney Lake). Since many users fish from multiple locations, multiple answers were accepted. Fishing locations are presented in Table 29.

Since these interviews were conducted only during summer, the distribution of use shown in Table 30 should be viewed as summer users of the lakes, not as representative of the total user population.

Fishing during the summer was rated as shown in Table 31. The frequencies are weighted to the middle to lower end of the 1 to 5 - LOW to HIGH QUALITY scale. Bass is the species of fish that is fished most heavily at these lakes during the summer followed by trout, walleye and perch, and sunfish, pike, bream, and crappie.

Fishing during the fall showed a similar pattern as summer, except for absence of trout fishing (Table 32). Winter fishing is primarily for bass, walleye, perch, and crappie (Table 33). Spring fishing included the same species as summer, including trout (Table 34).

The distribution of fishing by lake depths is shown in Table 35 (Question 15). Rating of fishing at each of the depth is summarized in Tables 36 to 39.

Of the fourteen respondents that fished in the surface water (Table 36), only one mentioned the thermocline as an explanation for rating of surface fishing. Four respondents cited the ease of fishing in surface water and four said there is better fishing in the surface water. Three respondents fished

for particular species (pan fish, bass, and trout) in the surface and two fished there because of use of particular lures or fly fishing.

Explanations of ratings for rating of surface fishing were dependent on fishing success. Eight respondents attributed their ratings to fishing success ("catch fish," get most [fish]) while six respondents attributed their rating to "No fish biting" or "Bad fishing". One respondent indicated fishing is variable.

Of the twenty respondents that fish in the middle depths (Table 37) eighteen gave reasons. One response directly referenced water quality or fish habitat ("shady and debris for feeding," but seven (7) fished in middle depths because more fish are in that depth and three (3) respondents said there is better fishing there and equal number were unsure or had no reason.

Two respondents said they fish in the middle depths because of particular fishing gear: one with lure and one with cork. Fishing for bass was the explanation of a single respondent. Another respondent said the middle depths follow the river channel.

For explanations of the ratings of quality for middle depths fishing, a pattern similar to surface fishing is evident. Eight respondents gave explanations of their ratings of middle depth fishing. Of these, three indicated fishing was good ("fish bite there," "Best place for fish"). An equal number (3) said there were "No fish" or "Bad fishing." One respondent said fishing is consistent in middle depths.

For those respondents that fished in bottom depths (Table 38), there is a clear relation between water temperature and the presence of fish. Those that fish in bottom waters (11 responses) cited either coldwater fish or particular species most often as the reason for fishing the bottom waters (4 responses). Three responses (3) said the water is cold on the bottom and two said "fish are there." A single respondent said he fished on the bottom because of a specific bait.

Three respondents explained ratings for bottom fishing, one said it is variable, and two indicated bad fishing success.

Of the seven tailwater fishers, (Table 39) five respondents provided explanations. Two (2) said that the abundance of fish in the tailwater is the reason for fishing there. Another mentioned the tailwater is easy to get to. Two others mentioned particular species as the reason for fishing the tailwater, one for pike and one for bass.

Three respondents explained ratings of tailwater fishing quality. The explanations were evenly apportioned: one as "Lot of fish," one "Bad fishing," and one "Not great."

Tailwater Use

Perceptions of water quality in the tailwater indicate lower ratings for clearness of the water, water level and scum in the water. Of those surveyed 18.1% of all respondents use the tailwater (Table 40). Of the respondents 9 (64.3%) said there is no difference in water quality in the tailwater (Table 41).

The ratings of water quality parameters for the tailwater are presented in Table 42 to 51 (Question 25).

Besides the tailwater user questions in Question 25, two questions about water temperature and recreation in the tailwater were asked (Tables 44 and 45).

Of the other tailwater water quality parameters, debris in the tailwater was about equally distributed along the rating scale (Table 46). The tailwater flow or volume is perceived on the medium to high end of the scale (Table 49). The absence of aquatic plants in the tailwater results in high ratings for that parameter (Table 48). Low ratings were given for odor in the tailwater (Table 49). The water levels in the tailwater are rated primarily in the middle and high (3-4) range (Table 50). Scum in the tailwater is apparently a concern, with low ratings for Whitney Point Lake and a more even distribution of rating for East Sidney Lake (Table 51).

Measures to Improve Water Quality

Respondents were highly supportive of land use and enforcement actions to protect water quality and about equally opposed to use of chemicals in the water (Tables 52 to 55).

QUESTIONNAIRE

OMB No. 0702-0016
Expires Oct. 31, 1989

1. NUMBER__________
2. LOCATION__________
3. DATE__________
4. INTERVIEWER__________

INTRODUCTION I am with the Corps of Engineers. We are doing a study of recreation use at ______ Lake in conjunction with a larger study of water quality conditions at the lake. I would like you to answer a few questions about your use of the lake.

IF RESPONDENT AGREES, CONTINUE, SAY,

Thank you, Now I must choose the person in your party who will actually answer the questions. <Random Selection Process>

IF RESPONDENT REFUSES, SAY
My questions will only take 10-15 minutes. You were selected as part of representative sample, so your answers are very important. Your answers are confidential and will be reported as statistics.

IF RESPONDENT REFUSES AGAIN, SAY Thank You. Please enjoy your visit.

5. Is this your first trip to __________ Lake?

6. About how often do you normally use the lake during the following seasons?

A. Never B. 1 to 5 times C. 6 to 10 times D. Over 10 times

___ Fall
___ Winter
___ Spring
___ Summer

7. Why do you choose this lake instead of some other lake ?

____

____

This study is designed to help the Corps of Engineers determine perceptions of water quality by users of the lake. This information will be used together with a study of the water quality conditions here at Lake ______ to develop suggested operational guidelines for the enhancement of water quality and recreational uses.

I'm going to ask you about recreation activities that may you participate in throughout the year at __________, and some questions about water quality.

*****BOATING*****BOATING*****BOATING****BOATING*****BOATING*****

8. Do you ever boat or sail on the lake?

___ YES ___ NO

If YES,

9. What kind of boat do you normally use?

1.	Cabin Cruiser	6.	Rowboat
2.	Runabout	7.	Canoe
3.	Houseboat	8.	Pontoon Boat
4.	Sailboat	9.	Bass Boat
5.	Boardsail	10.	Other________________

Based on this scale, how strongly do you agree or disagree with these statements, going from STRONGLY DISAGREE to STRONGLY AGREE

10. Water quality conditions interfere with boat operation	SD	D	U	A	SA
11. Green scum in the water is a nuisance	SD	D	U	A	SA
12. Debris in the water is hazardous to boaters	SD	D	U	A	SA

13. While you are boating, do you do the following?

Y N Swim from boat
Y N Ski
Y N Other________________

*******FISH*******FISH********FISH*****FISH*******FISH*******

14. Do you ever fish at the lake? ____ YES ____ NO

If YES,

_____ Fish from Boat
_____ Bank Fishing
_____ Wade in the lake
_____ Fish from pier, dock, boat launch
_____ Ice Fishing
_____ Tailwater
_____ Other

I need to find out the seasons that you fish, what type of fish you catch, and how you rate the fishing during that season on a 1 to 5 scale, going from 5 as HIGH QUALITY to 1 as LOW QUALITY fishing.

SEASON	HIGH QUALITY LOW QUALITY	Fish
Summer	5---4---3---2---1	______
Fall	5---4---3---2---1	______
Winter	5---4---3---2---1	______
Spring	5---4---3---2---1	______
Other	5---4---3---2---1	______

15. What depth of the lake waters do you usually fish in, and why?

		WHY
____	Surface water	______
____	Midway down in the lake (center of the water column)	______
____	Bottom of the lake	______
____	Tailwater	______
____	Other______	

16. How would you rate the fishing at each of the depths, and why? using the 5 to 1 scale with 5 as HIGH QUALITY and 1 as LOW QUALITY?

	HIGH QUALITY LOW QUALITY	WHY
Surface Water	5---4---3---2---1	______
Midway Down	5---4---3---2---1	______
Bottom	5---4---3---2---1	______
Tailwater	5---4---3---2---1	______
Other	5---4---3---2---1	______

*****RECREATION AREA USERS-BEACH*****************************

17. Do you ever use the lake beach or shore for:

Y N Sunbathing,
Y N Swimming from beach
Y N Beach activities
___ Water Contact
___ Non-water contact

****

18. How would you rate the overall water quality at Lake ________ on a 5 to 1 scale with 5 being HIGH QUALITY and 1 being LOW QUALITY?

HIGH QUALITY LOW QUALITY
5---4---3---2---1

A number of factors affect people's use and enjoyment of the water including:

Lake water levels
Clearness of the water

Temperature of the water
Debris in the water
Flow in the tailwater (fast or slow running)
Aquatic plants in the water
Odor
Tailwater levels
Scum in the water

19. Concerning the recreation activities you participate in, how important are these water quality factors, on a 5 to 1 scale with 5 being VERY IMPORTANT and 1 being NOT IMPORTANT?

	VERY IMPORTANT	NOT IMPORTANT
___ High lake level	5---4---3---2---1	
___ Clear water	5---4---3---2---1	
___ Warm water	5---4---3---2---1	
___ Lack of debris	5---4---3---2---1	
___ Moderate flow in the tailwater	5---4---3---2---1	
___ Absence of aquatic plants	5---4---3---2---1	
___ No obnoxious odors	5---4---3---2---1	
___ High tailwater level	5---4---3---2---1	
___ No scum in the water	5---4---3---2---1	

Comments:____
____
____

20. Do you think water quality needs to be improved at Lake ______?

____ NO ___ YES

21. IF YES,
If work is done to improve water quality, rank the four (4) most important water quality conditions that should be improved, going from 1 as HIGHEST PRIORITY

___ Lake water level
___ Clearness of the water
___ Temperature of the water
___ Debris in the water
___ Flow in the tailwater
___ Aquatic plants in the water
___ Odor
___ Tailwater levels
___ Scum in the water
____ Other____________________________

Now I am going to ask some questions about your visit here today.

22. Which of the activities did you participate in today ?

____ Boating
____ Fishing
____ Beach Activities
____ Other

23. On a scale of 1 to 10 (with 10 being the perfect trip) how would you rate the quality of this visit ?

____

WHY ? ____

____

24. Do you ever use the tailwater below the dam ? Y N
If Y, then

25. Are the water quality conditions different at the tailwater than at this area?

_____Same _____Different

If Different, then rate the conditions for the tailwater on a 1 to 5 scale, with 5 being HIGH QUALITY and 1 being LOW QUALITY.

	HIGH QUALITY ... LOW QUALITY
Clearness of the water	5---4---3---2---1
Temperature of the water	5---4---3---2---1
Debris in the water	5---4---3---2---1
Flow in the tailwater	5---4---3---2---1
Aquatic plants in the water	5---4---3---2---1
Odor	5---4---3---2---1
Tailwater levels	5---4---3---2---1
Scum in the water	5---4---3---2---1

Based on the conditions at _________ Lake, I'd like you to tell me how much you agree or disagree with the following statements.

26. Water quality in the lake has improved over the years	SD	D	U	A	SA
27. The temperature of the water should be warmer for recreation in the tail-water and downstream of the dam	SD	D	U	A	SA
28. Algae do not affect my enjoyment of the lake	SD	D	U	A	SA
29. Water quality of the lake is just right	SD	D	U	A	SA
30. The water looks green sometimes	SD	D	U	A	SA

31. Water temperature is just right SD D U A SA

32. Algae or aquatic plants should be cleared out with chemicals SD D U A SA

33. Zoning and land use controls should be used to help keep the streams and lake clean SD D U A SA

34. Poor water quality conditions are caused by people fishing and swimming. SD D U A SA

35. The water looks cloudy sometimes. SD D U A SA

36. Water quality should be improved at Lake ____________ SD D U A SA

37. Water should be kept cooler to improve recreation in the tailwater SD D U A SA

38. Chemicals should not be used in the lake for plant control SD D U A SA

39. I would enjoy my trip more if water quality were improved SD D U A SA

40. Boaters don't affect water quality SD D U A SA

41. The state should enforce pollution laws and fine people that pollute the lake and nearby streams SD D U A SA

42. Because of the water quality conditions, I did not participate in some activities that I wanted today:
Activities:____________ SD D U A SA

43. How far did you travel to get to the lake ?______
(Check to see that this is ONE WAY distance)

44. Zip code of Respondent____________

45. City________________ 46. State____________

Thank You!

Table 1

Proportion of Recreation Activities

	Both Lakes	Whitney Point	East Sidney
Fishing	34.9%	23.1%	46.7%
Boating	51.5%	42.3%	62.2%
Beach Activities	74.2%	95.2%	56.9%

Table 2

Frequency of Summer Use (6)*

	Number of Respondents	Percentage
Never	1	1.1
1 to 5 times	30	32.3
6 to 10 times	11	11.8
Over 10 times	51	54.8
	N = 93	

* Numbers in parentheses next to questionnaire questions or statements refer to the number in the questionnaire.

Table 3

Distance Travelled to the Lake (43)

	Both Lakes	Whitney Point	East Sidney
0-10 miles	27(28.4)*	8(15.4)	19(44.2)
11-20 miles	36(37.9)	24(46.1)	12(27.9)
21-30 miles	21(22.1)	16(30.8)	5(11.6)
31-40 miles	6(6.3)	4(7.7)	2(4.7)
41-50 miles	3(3.2)		3(6.9)
51-60 miles	2(2.1)		2(4.7)

Table 4

Reasons for Choosing the Lake (7)

	Both Lakes	Whitney Point	East Whitney
Closer	67(48%)	33(61.2)	34(61.8)
Facilities	23(17.3)	13(16.6)	10(18.2)
Not Crowded	13(10)	11(14.1)	2(3.6)
Can Use Jet Ski (East Sidney)			3(5.4)

Table 5

Ratings of Overall Water Quality

Rating	Both Lakes	Whitney Point	East Sidney
1 Low	0	0	0
2	2 (2.2)	1 (2.0)	1 (2.4)
3	34 (37.4)	20 (40.0)	14 (34.1)
4	35 (38.5)	20 (40.0)	15 (36.6)
5 High	20 (22.0)	9 (18.0)	11 (26.8)

Table 6

Water Quality of the Lake is Just Right (29)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	1 (1.1)	0	1 (2.3)
Disagree	14 (14.6)	6 (11.5)	8 (18.2)
Undecided	11 (11.5)	6 (11.5)	5 (11.4)
Agree	65 (67.7)	37 (71.2)	28 (63.6)
Strongly Agree	5 (5.2)	3 (3.8)	2 (4.5)

Table 7

Water Quality has Improved Over the Years (26)

Rating	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	1 (1.1)	0	1 (2.6)
Disagree	6 (6.7)	2 (3.8)	4 (10.5)
Undecided	45 (50.0)	31 (59.6)	14 (36.8)
Agree	34 (37.8)	18 (34.6)	16 (42.1)
Strongly Agree	4 (4.4)	1 (1.9)	3 (7.9)

Table 8

Water Quality Should be Improved (20)

	Both Lakes	Whitney Point	East Sidney
No	69 (72.6)	41 (80.4)	28 (63.6)
Yes	26 (27.4)	16 (36.4)	10 (19.6)

Table 9

Water Quality Should be Improved at Lake (36)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	2 (2.1)	1 (1.9)	1 (2.3)
Disagree	42 (44.2)	23 (44.2)	19 (44.2)
Undecided	20 (21.1)	12 (23.1)	8 (18.6)
Agree	28 (29.5)	15 (28.8)	13 (30.2)
Strongly Agree	3 (3.2)	1 (1.9)	2 (4.7)

Table 10

Because of the water quality conditions, I did not participate in some activities that I wanted today (42)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	8 (8.5)	2 (3.8)	6 (14.3)
Disagree	83 (88.3)	49 (94.2)	34 (81.0)
Undecided	1 (1.1)	1 (1.9)	0
Agree	2 (2.1)	0	2 (4.8)
Strongly Agree	0	0	0

Table 11

Water quality conditions interfere with boat operation (10)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	5 (10.2)	3 (13.6)	2 (7.4)
Disagree	32 (65.3)	12 (54.5)	20 (74.1)
Undecided	3 (6.1)	1 (4.5)	2 (7.4)
Agree	7 (14.3)	4 (18.2)	2 (7.4)
Strongly Agree	2 (4.1)	2 (9.1)	3 (11.1)

Table 12

I would enjoy my trip more if water quality were improved (39)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	1 (1.1)	0	1 (2.3)
Disagree	53 (55.8)	25 (49.0)	28 (63.6)
Undecided	15 (15.8)	13 (25.5)	2 (4.5)
Agree	24 (25.3)	12 (23.5)	12 (27.3)
Strongly Agree	2 (2.1)	1 (2.0)	1 (2.3)

Table 13

Poor Water Quality is Caused by People Fishing and Swimming (34)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	17(17.7)	9(17.3)	8(18.2)
Disagree	75(78.1)	39(75.0)	36(81.8)
Undecided	2(2.1)	2(3.8)	0
Agree	2(2.1)	2(3.8)	0
Strongly Agree	0	0	0

Table 14

Boaters Do Not Affect Water Quality (40)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	9(9.5)	2(3.8)	7(16.3)
Disagree	44(46.3)	17(32.7)	27(62.8)
Undecided	3(3.2)	3(5.8)	0
Agree	39(41.1)	30(57.7)	9(20.9)
Strongly Agree	0	0	0

Table 15

Priority Ranking

Priority	1	2	3
Clearness	14	4	2
Odor	5	4	1
Debris	3	2	6
Scum in the water	1	5	2

Table 16

Ratings for Clear Water (19)

	Both Lakes	Whitney Point	East Sidney	Rating	
Clear	0	0	0	1	Not imp.
Water	3(3.2)	1(2.0)	2(4.7)	2	
	12(12.8)	6(11.8)	6(14.0)	3	
	36(38.3)	21(41.2)	15(34.9)	4	
	43(45.7)	23(45.1)	20(46.5)	5	Most imp.

Table 17

Water Looks Green Sometimes (30)

	Both Lakes	Whitney Point	East Sidney
Strongly disagree	3(3.2)	1(1.9)	2(4.7)
Disagree	22(23.2)	11(21.2)	11(25.6)
Undecided	13(13.7)	11(21.2)	2(4.7)
Agree	43(45.3)	22(42.3)	21(48.8)
Strongly agree	14(14.7)	7(13.5)	7(16.3)

Table 18

Water Looks Cloudy Sometimes (35)

	Both Lakes	Whitney Point	East Sidney
Strongly disagree	1(1.0)	0	1(2.3)
Disagree	26(27.1)	13(25.0)	13(29.5)
Undecided	8(8.3)	6(11.5)	2(4.5)
Agree	56(58.3)	30(57.7)	26(59.1)
Strongly agree	5(5.2)	3(5.8)	2(4.5)

Table 19

No Obnoxious Odors (19)

	Both Lakes	Whitney Point	East Sidney	Rating
No	0	0	0	1 Not imp.
obnoxious	5 (5.5)	2 (4.2)	3 (7.0)	2
odors	2 (2.2)	1 (2.1)	1 (2.3)	3
	17 (18.7)	7 (14.6)	10 (23.3)	4
	67 (73.6)	38 (79.2)	29 (67.4)	5 Most imp.

Table 20

Rating for Lack of Debris (19)

	Both Lakes	Whitney Point	East Sidney	Rating
Lack	1 (1.1)	1 (2.0)	0	1 Not imp.
of	4 (4.3)	1 (2.0)	3 (7.0)	2
debris	11 (11.8)	9 (18.0)	2 (4.7)	3
	21 (22.6)	10 (20.0)	11 (25.6)	4
	56 (60.2)	29 (58.0)	27 (62.8)	5 Most imp.

Table 21

Debris is Hazardous to Boaters (12)

	Both Lakes	Whitney Point	East Sidney
Strongly disagree	2 (4.1)	0	2 (7.4)
Disagree	20 (40.8)	11 (50.0)	9 (33.3)
Undecided	2 (4.1)	2 (9.1)	0
Agree	19 (38.8)	6 (27.3)	13 (48.1)
Strongly agree	6 (12.2)	3 (13.6)	3 (11.1)

Table 22

Scum in the Water (19)

	Both Lakes	Whitney Point	East Sidney	Rating
Scum	2 (2.2)	2 (4.0)	0	1 Not imp.
in the	2 (2.2)	0	2 (4.7)	2
Water	4 (4.3)	2 (4.0)	2 (4.7)	3
	26 (28.0)	11 (22.0)	15 (34.9)	4
	59 (63.4)	35 (70.0)	24 (55.8)	5 Most imp.

Table 23

Scum is a Nuisance (11)

	Both Lakes	Whitney Point	East Sidney
Strongly disagree	3 (6.1)	1 (4.5)	2 (7.4)
Disagree	31 (63.3)	13 (59.1)	18 (66.7)
Undecided	1 (2.0)	1 (4.5)	0
Agree	11 (22.4)	6 (27.3)	5 (18.5)
Strongly agree	3 (6.1)	1 (4.5)	2 (7.4)

Table 24

Algae do not affect my enjoyment of the lake (28)

	Both Lakes	Whitney Point	East Sidney
Strongly disagree	7 (7.3)	2 (3.8)	5 (11.4)
Disagree	46 (47.9)	23 (44.2)	23 (52.3)
Undecided	5 (5.2)	2 (3.8)	3 (6.8)
Agree	31 (32.3)	21 (40.4)	10 (22.7)
Strongly agree	7 (7.3)	4 (7.7)	3 (6.8)

Table 25

Presence of Aquatic Plants (19)

	Both Lakes	Whitney Point	East Sidney	Rating
Absence	15 (16.1)	12 (24.0)	3 (7.0)	1 Not imp.
of	4 (4.3)	4 (8.0)	0	2
Aquatic	15 (16.1)	6 (12.0)	9 (20.9)	3
Plants	30 (32.3)	20 (40.0)	10 (23.3)	4
	29 (31.2)	8 (16.0)	21 (48.8)	5 Most imp.

Table 26

Temperature is Just Right (31)

	Both Lakes	Whitney Point	East Sidney
Strongly disagree	1 (1.0)	1 (1.9)	0
Disagree	6 (6.2)	3 (5.8)	3 (6.8)
Undecided	5 (5.2)	4 (7.7)	1 (2.3)
Agree	73 (76.0)	36 (69.2)	37 (84.1)
Strongly agree	11 (11.5)	8 (15.4)	3 (6.8)

Table 27

Ratings for Warm Water (19)

	Both Lakes	Whitney Point	East Sidney	Rating
Warm	6 (6.5)	4 (7.8)	2 (4.9)	1 Not imp.
water	8 (8.7)	7 (13.7)	1 (2.4)	2
	26 (28.3)	16 (31.4)	10 (24.4)	3
	37 (40.2)	15 (29.4)	22 (53.7)	4
	15 (16.3)	9 (17.6)	6 (14.6)	5 Most imp.

Table 28

Rating for High Lake Level

	Both Lakes	Whitney Point	East Sidney
High	7(7.4)	5(9.8)	2(4.7)
	9(9.6)	6(11.8)	3(7.0)
Lake	13(13.8)	6(11.8)	7(16.3)
	36(38.3)	17(33.3)	19(44.2)
Level	29(30.9)	17(33.3)	12(27.9)

Table 29

Distribution of Fishing Locations (14)

	Both Lakes	Whitney Point	East Sidney
Fishing from boat	16	6	10
Bank fishing	23	11	13
Wade in lake	4	1	3
Fish from pier/dock	5	0	5
Ice fishing	2	1	1
Tailwater fishing	8	2	6

Table 30

Seasonal Fishing Use (14)

	Both Lakes	Whitney Point	East Sidney
Summer	32	12	20
Fall	11	9	2
Winter	5	5	0
Spring	7	6	1

Table 31

Rating of Summer Fishing

Rating	Both Lakes	Whitney Point	East Sidney
1	6 (18.8)	4 (33.3)	2 (10.0)
2	5 (15.6)	0	5 (25.0)
3	11 (34.4)	3 (25.0)	8 (40.0)
4	4 (12.5)	1 (8.3)	3 (15.0)
5	6 (18.8)	4 (33.3)	2 (10.0)
	N = 32	N = 12	N = 20

Table 32

Ratings for Fall Fishing

Rating	Both Lakes	Whitney Point	East Sidney
1	0	0	0
2	2 (18.2)	1 (11.1)	1 (50)
3	4 (36.4)	4 (44.4)	0
4	3 (27.3)	3 (33.3)	0
5	2 (18.2)	1 (11.1)	1 (50)
	N = 11	N = 9	N = 2

Table 33

Rating of Winter Fishing

Rating	Both Lakes	Whitney Point	East Sidney
1	1 (20.0)	1 (20.0)	0
2	1 (20.0)	1 (20.0)	0
3	3 (60.0)	3 (60.0)	0
4	0	0	0
5	0	0	0
	N = 5	N = 5	

Table 34

Rating of Spring Fishing

	Both Lakes	Whitney Point	East Sidney
1	0	0	0
2	1 (14.3)	0	1 (100)
3	3 (42.9)	3 (50.0)	0
4	3 (42.9)	3 (50.0)	0
5	0	0	0
	N = 7	N = 6	N = 1

Table 35

Fishing by Lake Depths

	Both Lakes	Whitney Point	East Sidney
Surface	14	4	10
Midway	20	10	10
Bottom	13	5	8
Tailwater	7	2	5

Table 36

Rating for Surface Fishing

Rating	Both Lakes	Whitney Point	East Sidney
1	2 (11.8)	0	2 (15.4)
2	3 (7.6)	0	3 (23.1)
3	6 (35.3)	2 (50.0)	4 (30.8)
4	3 (17.6)	1 (25.0)	2 (15.4)
5	3 (17.6)	1 (25.0)	2 (15.4)
	N = 17	N = 4	N = 13

Table 37

Ratings for Middle Depth

Rating	Both Lakes	Whitney Point	East Sidney
1	2 (11.1)	2 (20.0)	0
2	1 (5.6)	0	1 (12.5)
3	4 (22.2)	3 (30.0)	1 (12.5)
4	8 (44.4)	3 (30.0)	5 (62.5)
5	3 (16.7)	2 (20.0)	1 (12.5)
	N = 18	N = 10	N = 8

Table 38

Ratings for Bottom Fishing

Rating	Both Lakes	Whitney Point	East Sidney
1	2 (15.4)	0	2 (25.0)
2	4 (30.8)	1 (20.0)	3 (37.5)
3	1 (7.7)	1 (20.0)	0
4	3 (23.1)	1 (20.0)	2 (25.0)
5	3 (23.1)	2 (40.0)	1 (12.5)
	N = 13	N = 5	N = 8

Table 39

Ratings for Tailwater Fishing

Rating	Both Lakes	Whitney Point	East Sidney
1	0	0	0
2	1 (16.7)	1 (50.0)	0
3	2 (33.3)	0	2 (50)
4	2 (33.3)	1 (50.0)	1 (25)
5	1 (16.7)	0	1 (25)
	N = 6	N = 2	N = 4

Table 40

Do you ever use the tailwater below the dam? (24)

	Both Lakes	Whitney Point	East Sidney
Yes	17 (18.1)	8 (15.4)	9 (21.4)
No	77 (81.9)	44 (84.6)	33 (78.6)

Table 41

Are the water quality conditions different at the tailwater than at this area? (25)

	Both Lakes	Whitney Point	East Sidney
Yes	5 (35.7)	4 (50)	1 (16.7)
No	9 (64.3)	4 (50)	5 (83.3)

Table 42

Clearness of the Water

Rating	Both Lakes	Whitney Point	East Sidney
1 Low	0	0	0
2	3 (27.3)	2 (40.0)	1 (16.7)
3	4 (36.4)	2 (40.0)	2 (33.3)
4	2 (18.2)	0	2 (33.3)
5 High	2 (18.2)	1 (20.0)	1 (16.7)
		N = 11	N = 5
N = 6			

Table 43

Temperature of the Water

Rating	Both Lakes	Whitney Point	East Sidney
1 Low	0	0	0
2	2 (20.0)	1 (20.0)	1 (20.0)
3	4 (40.0)	2 (40.0)	2 (40.0)
4	2 (20.0)	1 (20.0)	1 (20.0)
5 High	2 (20.0)	1 (20.0)	1 (20.0)
	N = 10	N = 5	N = 5

Table 44

The temperature of the water should be kept cooler to improve recreation in the tailwater (37)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	1(3.1)	1(5.6)	6(42.9)
Disagree	17(53.1)	11(61.1)	1(7.1)
Undecided	4(12.5)	3(16.7)	6(42.9)
Agree	8(25.0)	2(11.1)	1(7.1)
Strongly Agree	2(6.2)	1(5.6)	

Table 45

The temperature of the water should be warmer for recreation in the tailwater and downstream of the dam (27)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	1(3.1)	0	1(5.0)
Disagree	21(65.6)	5(41.7)	16(80.0)
Undecided	2(6.2)	2(16.7)	0
Agree	8(25.0)	5(41.7)	3(15.0)
Strongly Agree	0	0	0

Table 46

Debris in the Tailwater

Rating	Both Lakes	Whitney Point	East Sidney
1 Low	1 (9.1)	1 (20.0)	0
2	4 (36.4)	1 (20.0)	3 (50.0)
3	1 (9.1)	1 (20.0)	0
4	4 (36.4)	1 (20.0)	3 (50.0)
5 High	1 (9.1)	1 (20.0)	0
	N = 11	N = 5	N = 6

Table 47

Flow in the Tailwater

Rating	Both Lakes	Whitney Point	East Sidney
1 Low	0	0	0
2	2 (18.2)	0	2 (33.3)
3	2 (18.2)	1 (20.0)	1 (16.7)
4	4 (36.4)	2 (40.0)	2 (33.3)
5 High	3 (27.3)	2 (40.0)	1 (16.7)
	N = 11	N = 5	N = 6

Table 48

Ratings for Aquatic Plants in the Tailwater

Rating	Both Lakes	Whitney Point	East Sidney
1 Low	0	0	0
2	1 (10.0)	0	1 (20.0)
3	1 (10.0)	1 (20.0)	0
4	6 (60.0)	0	2 (40.0)
5 High	2 (20.0)	4 (80.0)	2 (40.0)
	N = 10	N = 5	N = 5

Table 49

Ratings for Tailwater Odor

Rating	Both Lakes	Whitney Point	East Sidney
1 Low	1 (9.1)	0	1 (16.7)
2	3 (27.3)	2 (40.0)	1 (16.7)
3	2 (18.2)	2 (40.0)	0
4	0	0	0
5 High	5 (45.5)	1 (20.0)	4 (66.7)
	N = 11	N = 5	N = 6

Table 50

Ratings for Tailwater Levels

Rating	Both Lakes	Whitney Point	East Sidney
1 Low	0	0	0
2	1 (8.3)	0	1 (16.7)
3	6 (50.0)	4 (66.7)	2 (33.3)
4	4 (33.3)	2 (33.3)	2 (33.3)
5 High	1 (8.3)	0	1 (16.7)
	N = 12	N = 6	N = 6

Table 51

Ratings for Scum in the Water

Rating	Both Lakes	Whitney Point	East Sidney
1 Low	0	0	0
2	3 (27.3)	2 (40.0)	1 (16.7)
3	4 (36.4)	2 (40.0)	2 (33.3)
4	2 (18.2)	0	2 (33.3)
5 High	2 (18.2)	1 (20.0)	1 (16.7)
	N = 11	N = 5	N = 6

Table 52

Algae or aquatic plants should be cleared out with chemicals (32)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	51 (53.7)	29 (55.8)	22 (51.2)
Disagree	30 (31.6)	19 (36.5)	11 (25.6)
Undecided	6 (6.3)	1 (1.9)	5 (11.6)
Agree	7 (7.4)	3 (5.8)	4 (9.3)
Strongly Agree	1 (1.1)	0	1 (2.3)

Table 53

Chemicals should not be used in the lake for plant control (38)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	4 (4.2)	1 (2.0)	3 (6.8)
Disagree	10 (10.5)	2 (3.9)	8 (18.2)
Undecided	7 (7.4)	3 (5.9)	4 (9.1)
Agree	33 (34.7)	20 (39.2)	13 (29.5)
Strongly Agree	41 (43.2)	25 (49.0)	16 (36.4)

Table 54

Zoning and land use controls should be used to help keep the streams and lakes clean (33)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	1 (1.0)	1 (1.9)	0
Disagree	3 (3.1)	2 (3.8)	1 (2.3)
Undecided	3 (3.1)	2 (3.8)	1 (2.3)
Agree	54 (56.3)	32 (61.5)	22 (50.0)
Strongly Agree	35 (36.5)	15 (28.8)	20 (45.5)

Table 55

The state should enforce pollution laws and fine people that pollute the lake and nearby streams (41)

	Both Lakes	Whitney Point	East Sidney
Strongly Disagree	1 (1.0)	0	1 (2.3)
Disagree	1 (1.0)	1 (1.9)	0
Undecided	0	0	0
Agree	41 (42.7)	21 (40.4)	20 (45.5)
Strongly Agree	53 (55.2)	30 (57.7)	23 (52.3)

APPENDIX E: COMPUTER ASSESSMENT OF WATER QUALITY

The empirical reservoir water quality model, BATHTUB (Walker, 1987), was used to assess water quality conditions at Whitney Point and East Sidney Lakes. This model, based on a CE-wide database, uses theoretical concepts such as mass balance and nutrient limitation of phytoplankton growth. The model produces spatially and temporally averaged estimates of reservoir water quality conditions and does not attempt to explicitly simulate the dynamics of a reservoir. Water quality conditions are modeled in a two stage procedure involving two model types. First, a nutrient balance model is executed to relate pool or discharge nutrient concentrations to nutrient loads, morphometry, and hydrology. Second, a eutrophication response model is executed to relate pool nutrient concentrations to chlorophyll concentrations and transparency. These models produce estimates of steady-state, long-term, water quality conditions in the epilimnion and are not intended to predict or describe short-term, event-related dynamics in reservoirs or to generate vertical profiles of water quality conditions. Further details of the development, assumptions, and use of the empirical reservoir model can be found in Walker (1981; 1982; 1985; and 1987).

Water quality conditions for the summer growing season at Whitney Point and East Sidney Lakes were assessed with model simulation using BATHTUB and the results are summarized in Table E1. Modeling efforts were conducted with total sodium considered as a conservative tracer. At both lakes, the model of total sodium over predicted in-lake concentrations. Previously described loading calculations indicated that in-lake sodium concentrations increased during the growing season and suggest that sodium may not be conservative in this application. Total phosphorus, nitrogen, and chlorophyll _a_ concentrations were markedly underestimated with model application and Secchi disk depths were overestimated. Changes of in-lake concentrations (particularly marked increases observed in late summer) resulted in pronounced variability in model application. In fact, pronounced variability in model application precluded sensitivity analyses of changes in nutrient loading rates. Successful model application at Whitney Point and East Sidney Lakes requires more frequent data collection due to the highly variable response in water quality.

Table E1

Comparison of observed and predicted water quality conditions at Whitney Point and East Sidney Lakes (Summer Growing Season)

Variable *	Observed	Predicted	Percent Difference
Whitney Point Lake			
Total Sodium	4198.0	5607.8	25.1
CV	0.09	0.01	
Total Phosphorus	35.9	19.3	86.0
CV	0.15	0.13	
Total Nitrogen	706.0	537.9	31.2
CV	0.02	0.16	
Chlorophyll *a*	18.1	7.0	158.6
CV	0.81	0.36	
Secchi Disk Depth	1.1	1.6	31.2
CV	0.36	0.72	
East Sidney Lake			
Total Sodium	3882.0	4622.1	16.0
CV	0.08	0.39	
Total Phosphorus	24.1	14.2	69.7
CV	0.16	0.24	
Total Nitrogen	731.0	506.4	44.4
CV	0.10	0.37	
Chlorophyll *a*	14.0	4.7	197.9
CV	0.89	0.46	
Secchi Disk Depth	2.8	5.0	44.0
CV	0.64	2.01	

* Concentrations in mg/cu m except for Secchi Disk Depth which is in meters.

APPENDIX F: EVALUATION OF ARTIFICIAL CIRCULATION AT EAST SIDNEY LAKE

Thermal stratification occurs when heat gain through the surface of a lake or reservoir creates density differences between top and bottom strata. For shallow bodies of water, stratification may occur intermittently, since wind shear at the surface often provides enough energy to completely mix the water column. However, as depth increases, the amount of work required to completely mix the water column also increases. For temperate lakes with depths greater than 10-15 meters, density stratification often persists until sufficient heat loss occurs at the end of summer. At this time, the lake will again be susceptible to the mixing force of wind shear.

During periods of thermal stratification, mixing below the zone of maximum change in water density (i.e., the thermocline) is limited and bottom waters become stagnant. If stratification persists for a long period of time significant changes in water quality can occur. For lakes which are highly productive or which receive heavy organic loads, oxygen stores in bottom waters will be insufficient to meet the respiratory needs of the microbial community and dissolved oxygen concentration will be greatly reduced. If the period of stratification is long, anoxic conditions may occur in bottom waters.

The loss of dissolved oxygen, which has obvious consequences for aerobic organisms, also markedly impacts water and sediment chemistry. Benthic communities are reduced or eliminated, and zooplankton and fish are limited to upper, well-mixed layers of the water column for extended periods of time.

Improvements in water quality have occurred for many lakes and reservoirs following destratification (Pastorak et al., 1982). These include improvements in both chemical and biological aspects of water quality. Increased mixing, due to reduced density differences, provides a mechanism for reaerating bottom waters normally isolated during periods of stratification. Oxic conditions, if persisting in strata normally anoxic under stratified conditions, reduce the concentrations of iron and manganese and expand the habitat of many organisms, including fish.

Reduction of internal nutrient loading, due to maintenance of oxygenated bottom water, may impact phytoplankton productivity. By reducing nutrient availability from bottom sediments, phytoplankton productivity may be reduced. Changes in nutrient availability may result in species competition which could

alter composition of the phytoplankton community. While these changes might favor less desirable species, such as blue-green species capable of nitrogen-fixing, limited phosphorus availability may help to reduce overall abundance or biomass of phytoplankton.

Maintenance of mixed conditions may in turn favor phytoplankton species without buoyancy capabilities such as diatoms. Vertical migration of phytoplankton for food and light resources may also be disrupted, thereby impacting productivity. Additionally, mixed conditions will lessen the severity of phytoplankton concentration at specific locations throughout the water column and in surface waters. Although biomass may not be less, increased phytoplankton dispersion will increase water clarity and improve aesthetic quality at the lake.

Three basic system types have been employed for the destratification of lakes and reservoirs; air-lift, mechanical, and water-jet systems. Air-lift systems rely on flows induced by a rising plume of air bubbles to mix the water column, while the latter two systems involve pumps to move water. Air-lift systems, while offering a degree of direct aeration, act as pumps when used for destratification. Reaeration, which is often a desired indirect effect of destratification, occurs primarily through enhancement of gaseous exchange at the air-water interface due to increased mixing. Experience with a variety of system types indicates that air-lift systems are least expensive and most easily operated (Lorenzen and Fast, 1977).

Regardless of the system used, proper design requires that enough energy be imparted to the water column to reduce differences in temperature from surface to bottom through mixing. In the case of air-lift systems, the release of compressed air from a manifold located near bottom results in the upwelling of cool hypolimnetic water. This reduces surface temperatures and increases bottom temperatures. If air flow rate is sufficient, circulation will involve the entire volume of the lake and temperature differences between surface and bottom waters will be minimal.

Based on theoretical considerations of relations between air release rate, column depth, and the rate of flow of upwelled water, Lorenzen and Fast (1977) determined the critical value for air flow rate for a variety of hypothetical lakes to be 9.2 cu m/min/sq km. A subsequent review of field data for 42 air-lift projects (Pastorak et al., 1982; Cooke et al., 1986) indicates that this value provides a good "rule-of-thumb" for sizing such systems, since air-flow rates below this value tended to incompletely destratify (i.e.

difference in temperature from surface to bottom greater than zero) the water column. Rates above this value allowed complete destratification.

Considerations of lake stability, lake heating, and energy requirements for mixing also provide a theoretical basis for designing air-lift systems (Davis, 1980). This method involves balancing the work required to reduce stability to a minimum and the heat input through the lake surface with the energy input by the mixing device. Davis (1980) also discusses considerations for manifold design and methods for anchoring systems. It is noteworthy that this method and the method of Lorenzen and Fast (1977) yield different design parameters (Pastorak et al., 1982).

Recent experiences in several Australian reservoirs (Burns, 1988) suggest that many previous systems may have been over-designed and/or operated inefficiently. While early attempts involved larger, manually-operated systems (Burns and Powling, 1981), smaller, automated systems currently perform well (Burns, 1988). Much efficiency is gained through automation. Temperature probes in the lake, one near the bottom and one near the surface, provide a continual check on the degree of stratification. At pre-determined settings of temperature difference, compressors are turned on for set periods of operation. At the end of this period, compressors are either turned off or cycled through another period of operation, depending upon the temperature difference.

Burns' (1988) report of destratification experiences at Little Bass Reservoir, Australia, provides an example of current technology and cost effectiveness. Little Bass Reservoir is a small (volume = 240,000 cu m; maximum depth = 10 m), water supply reservoir which has been destratified during the past seven years. During this period, several improvements in equipment design were made. The early system employed a manually-controlled, diesel compressor supplying an air flow 50 L/sec to a 12-m manifold located on the lake's bottom. This was replaced with a 3-kW electric compressor and automated controls were added to improve efficiency. During 1988/1989, an experimental, solar-powered, 1-kW compressor was operated successfully during the stratified season.

A series of temperature probes suspended in the Little Bass Reservoir allow automated control of compressor operation (Burns, 1988). The operational objective is a surface-to-bottom temperature difference of less than 0.6 degrees C; differences greater than this value indicate stratification and initiate compressor operation for a six-hour period. Using this method,

unnecessary periods of operation, as would potentially occur with a routine operation schedule and/or without a means to check lake conditions, were avoided. For example, the system was operated only 9 times (total of 54 hours) during a characteristic 7-day period in 1986. Only twice during this period did temperature differences exceed the 0.6 degree objective. Operational cost was approximately $5 (Aust.) per week.

A potential drawback for automated systems is that mixing may not always be adequate for achieving algal control. For periods when limited operation is required for the maintenance of destratification, algal biomass could increase to undesirable levels. During such periods, anoxia may develop in bottom sediments resulting in an increased availability of sedimentary phosphorus to phytoplankton via mixing.

Effects on Tailwater Quality

Improvements in discharge water quality will be reflected by decreased nutrient and metal concentrations. In particular, late summer concentrations of nutrients and metals in the discharge may be lower than concentrations observed late in the study period. Consequently, nutrient discharge losses will be lessened and impacts may occur downstream.

Additional potential impacts on downstream water quality, due to artificial circulation, pertain to changes in temperature and dissolved oxygen concentrations in release waters. These parameters were not routinely monitored during the study period so rigorous analyses are not possible. Predicted mid-summer temperature of mixed conditions was calculated from area-weighted temperatures during July, 1988 and was similar to historical data (Figure F1).

Recommendations

Artificial circulation using an air-lift mixing system is recommended for maintenance of mixed conditions during the summer growing season at East Sidney Lake. The recommended system would include an electric air compressor, distribution system, and a control system using a timer. Ideally, thermistors would be deployed in the lake to operate the system based on a predetermined temperature difference.

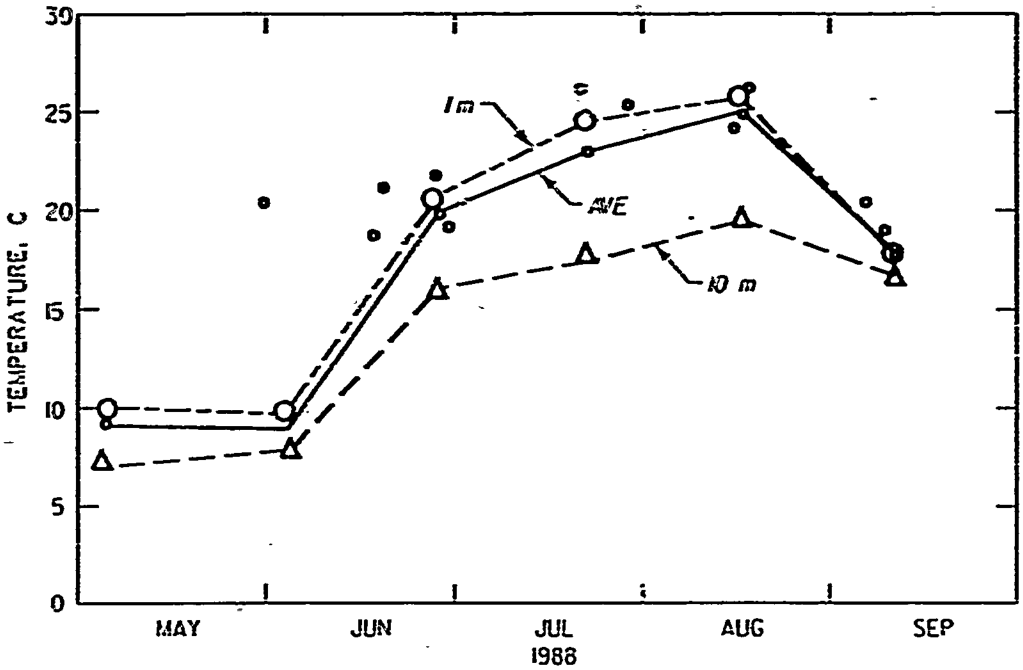

Figure F1. Surface, bottom, and mean water temperatures, East Sidney Lake, and historical discharge water temperatures (individual points)

Project benefits from reservoir mixing would include enhanced water quality in the lake and discharge. Water quality enhancement would be attributed to decreased materials cycling in bottom waters, thereby reducing discharge concentrations. Effects on the biota of the lake are less discernible but positive effects on reductions of phytoplankton biomass are anticipated. Implementation and operational costs have not been determined and should be considered.

Increased monitoring of discharge water quality is recommended to monitor effects of reservoir mixing, however rigorous comparisons with pretreatment conditions will be limited by sparse historical data.